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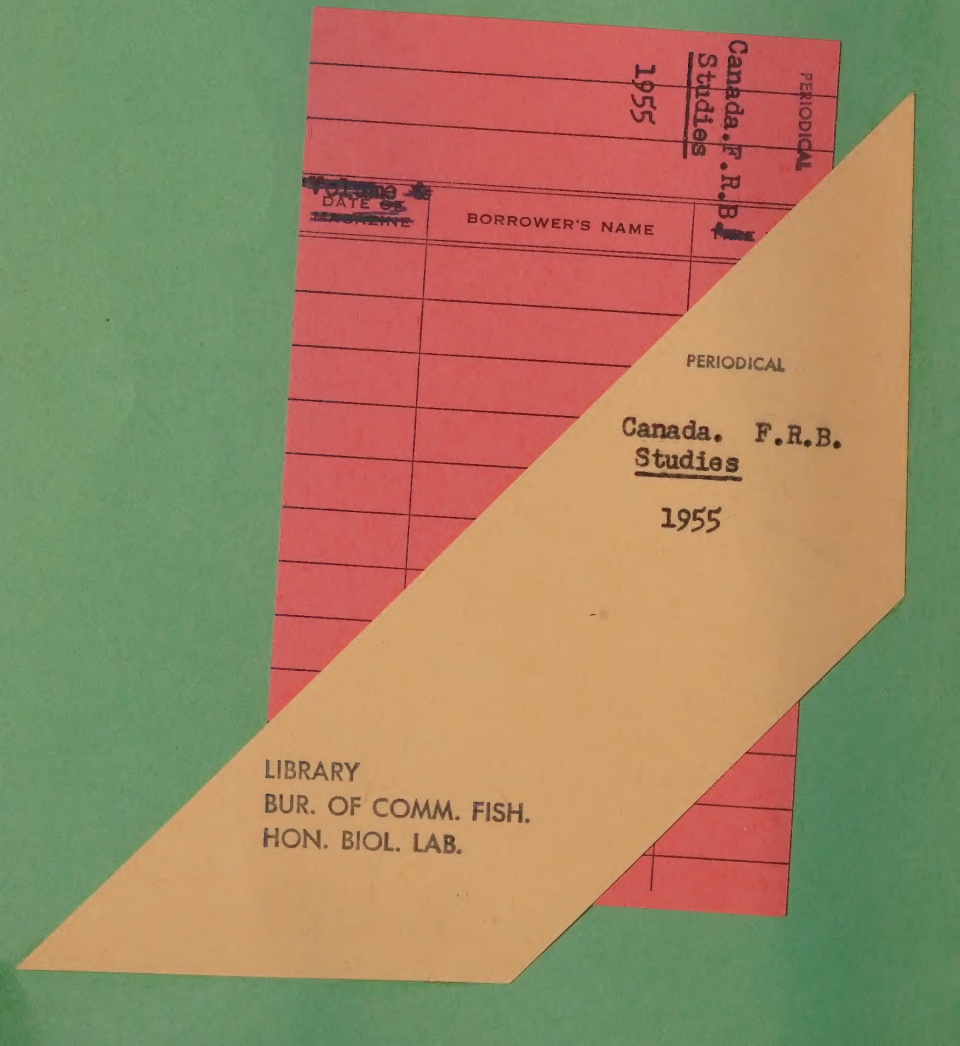
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BRITISH COLUMBIA DEPARTMENT OF FISHERIES, 1954

Contributions to the Life-history of the Sockeye Salmon

[PAPER 39.]

BY

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APPENDICES

CONTRIBUTIONS TO THE LIFE-HISTORY OF THE SOCKEYE SALMON (No. 39)

By D. R. Foskett, B.A., M.A., Pacific Biological Station, Nanaimo, B.C.

INTRODUCTION

This is the thirty-ninth report in a series reporting on the age of sockeye in the ommercial catch, the sex ratios, and the weights and lengths of the fish according to sex nd area of catch. The data cover the larger sockeye runs in British Columbia with the xception of the Fraser River. It must be pointed out, however, that the figures given are ıose for the catch and, as was shown in No. 38 of this series, do not necessarily represent ıe escapement. This, in addition to the fact that it is not yet known to what extent eredity and environment affect age of maturity in the Pacific salmon, seriously limits the alue of the data with regard to predicting the returns to be expected from a given run.

DESIGNATION OF AGE-GROUPS AND TREATMENT OF DATA

Two outstanding features in the life-history of the fish have been selected in desig- ating the age-groups—namely, the age at maturity and the year of its life in which the sh migrated from fresh water. These are expressed symbolically by two numbers—one ı large type, which indicates the age of maturity, and the other in small type, placed to ıe right and below, which signifies the year of life in which the fish left fresh water. The ge-groups which are met most commonly are:—

3_1, 4_1—the "sea types" or fish which migrate seaward in their first year and mature in their third and fourth year respectively.

3_2—"the grilse," almost exclusively males and frequently called "jacks," which migrate seaward in their second year and mature in their third year.

4_2, 5_2—fish which migrate seaward in their second year and mature in their fourth and fifth years respectively.

5_3, 6_3—fish which migrate seaward in their third year and mature in their fifth and sixth years respectively.

6_4, 7_4—fish which migrate seaward in their fourth year and mature in their sixth and seventh years respectively.

Fish were measured to the nearest quarter of an inch, but when averaged the average ıs been recorded to the nearest tenth of an inch to avoid using fractions or more than ıe decimal place. Weights were taken to the nearest tenth of a pound. This has resulted an even-pound and half-pound bias when the data are grouped to the nearest quarter- ound.

1. THE NASS RIVER SOCKEYE RUN OF 1953

(1) General Characteristics

In the forty-two years for which records are available for the Nass River sockeye e average catch has been 20,500 cases. The average for the past ten years has been ,814 cases and for the past five years 21,723 cases. The pack of 18,162½ cases for 53 is then about average for this area. The spawning report of the Federal Department

of Fisheries states that "the run of sockeye to the Nass system was light and the escape ment to the Meziadin Lake system, principal spawning-grounds for this species, wa also light."

(2) Age-groups

The Nass River sockeye sample was composed chiefly of 5_3, 4_2, and 5_2 age-clas fish with percentages of 45.7, 22.8, and 21.5, respectively. The only other age-clas represented in significant numbers was the 6_3 group which formed 8.8 per cent of th sample (Table I). Minor age-classes present are shown in Tables II and III.

(3) Lengths and Weights

The main group of the Nass River sockeye sample, the 5_3 fish, were approximatel average in size and weight (Tables II to V). The 5_2 fish, however, were quite large an heavy, as were the 4_2 and 6_3 groups (Tables II to V).

(4) Distribution of Sexes

There was nothing unusual in the sex ratio of the various age-classes in the Nas River sockeye sample (Table VI). The three main age-groups 4_2, 5_2, and 5_3 had se rations of 50:50, 44:56, and 46:54 respectively. The small 6_3 group had a sex ratio o 62 per cent males to 38 per cent females. The over-all ratio was 48 males to 52 females Jacks were reported as forming less than 1 per cent of the spawning population.

2. THE SKEENA RIVER SOCKEYE RUN OF 1953

(1) General Characteristics

The forty-seven-year average for the Skeena River sockeye-pack is 84,714 case The average for the past ten years has been 71,412 cases and for the last five year 70,978 cases. The pack in 1953 was 65,003 cases, a figure which is below the averag The closure of the fishery for ten days to allow a heavier escapement undoubtedly reduce the take of sockeye to some extent since the catch was 168,901 fish in the preceding wee and 208,923 in the week following the closure. The escapement was heavy in the Babin area, but other parts of the watershed had light to medium runs.

(2) Age-groups

The Skeena River sockeye sample in 1953 was composed chiefly of 4_2 (48 pe cent) and 5_2 (42.8 per cent) fish, the only other age groups present being 5_3 (6.2 pe cent), 6_3 (2.9 per cent), and 3_2 (0.1 per cent) (Tables VIII and IX). This means tha the return was 48 per cent from the 1949 spawning and 49 per cent from the 194 spawning.

(3) Lengths and Weights

The Skeena River sockeye, as shown by the sample, were large fish. Those in th 5_2 age-class exceeded the averages of the past eleven years (Tables X and XI). Excep for the length of the 4_2 males the 4_2 fish also exceeded the records of the past eleve years. The 6_3 sockeye exceeded recent weight records but not those of length.

(4) Distribution of Sexes

The sex ratio of the Skeena River sockeye sample was 39 males to 61 females, whic reflects the ratio for the two main age-classes, 40:60 for the 4_2 fish and 34:66 for th 5_2 group (Table XII). The ratios of 60:40 and 58:42 for the 5_3 and 6_3 age-class respectively have very little effect on the over-all ratio due to the small numbers of the fish present in the sample.

3. THE RIVERS INLET SOCKEYE RUN OF 1953

(1) General Characteristics

The pack of 132,925 cases was the fifth largest recorded for the Rivers Inlet area. It is only the second time that a pack of more than 75,000 cases has been composed of over 70 per cent 4-year-old fish in this area. Despite the large pack the spawning-grounds were well seeded. Though this run was largely the return from 1949, the poor pack in that year was not indicative of the size of the run, the escapement having been particularly heavy that year.

(2) Age-groups

As is normal for the Rivers Inlet area, the 4_2 and 5_2 age-classes comprised almost the whole of the run. However, as mentioned above, the proportion of 4_2 fish was decidedly above normal for a large-size run since this age-group formed 73 per cent of the sample (Table XIII).

(3) Lengths and Weights

The 4_2 sockeye in the Rivers Inlet sample were large but within the range for this age-class in this area. The 5_2 sockeye, however, were above the figures for the past eleven years in both length and weight (Tables XVI and XVII).

(4) Distribution of Sexes

As is the normal pattern for this area, the 4_2 males were more numerous than the 4_2 females, and the 5_2 males less numerous than the 5_2 females (Table XVIII). How much of this pattern is due to selection by the fishery and how much to a tendency on the part of the males to mature early is not at present known.

4. THE SMITH INLET SOCKEYE FISHERY OF 1953

(1) General Characteristics

The pack of 29,947 cases of sockeye from this area in 1953 is well above the average for the past twenty-nine years but is below the average of 33,976 cases for the last five years. As was the case with Rivers Inlet, the run in this area was largely (89 per cent) the return from the 1949 run.

(2) Age-groups

As indicated above, the 4_2 age-group formed 89 per cent of the Smith Inlet sockeye run in 1953 (Table XIX). The 5_2 sockeye formed 10 per cent of the run. Though the analysis of the age-groups in the Smith Inlet sockeye-catch has only been carried out since 1945, it is evident that the age composition of the run varies considerably. This is no doubt influenced by the fact that males in a population may tend to mature in greater numbers at 4 years of age and females in greater numbers at 5 years of age.

As mentioned above, the Smith Inlet sockeye were largely (89 per cent) 4_2 fish in the 1953 catch sample (Table XIX); 5_2 sockeye formed 10 per cent of the fish examined. Fish aged 5 and 6 years which had spent two years in the lake were present in minor numbers.

(3) Lengths and Weights

The length and weight of the 4_2 age-group sockeye in the Smith Inlet sample were large but within the ranges shown by past samples. The 5_2 group, however, was greater in both average length and weight than past samples (Tables XXII and XXIII).

(4) Distribution of Sexes

The normal sex ratio for the main age-classes in this area shows a preponderance of 4-year-old males and of 5-year-old females as mentioned previously. This year was no exception, the sex ratios being 60:40 for the 4_2 fish and 36:64 for the 5_2 fish. The over-all sex ratio, however, was 58 males to 42 females (Table XXIV), thus reflecting the dominance of 4_2 sockeye in the 1953 run to this area.

Table I.—Nass River Sockeyes, Percentages of Principal Age-groups in Runs of Successive Years and Packs

Year	Percentage of Individuals			
	4_2	5_2	5_3	6_3
1912 (36,037 cases)	8	27	63	2
1913 (23,574 cases)	15	12	71	2
1914 (31,327 cases)	4	41	45	10
1915 (39,349 cases)	19	14	59	8
1916 (31,411 cases)	9	17	66	8
1917 (22,188 cases)	10	15	71	4
1918 (21,816 cases)	30	16	45	9
1919 (28,259 cases)	7	22	65	6
1920 (16,740 cases)	8	14	72	6
1921 (9,364 cases)	10	7	75	8
1922 (31,277 cases)	6	2	91	1
1923 (17,821 cases)	11	6	77	6
1924 (33,590 cases)	4	3	91	2
1925 (18,945 cases)	23	8	67	2
1926 (15,929 cases)	12	12	63	13
1927 (12,026 cases)	8	7	81	4
1928 (5,540 cases)	30	6	61	3
1929 (16,077 cases)	25	9	60	6
1930 (26,405 cases)	28	15	54	3
1931 (16,929 cases)	10	17	67	6
1932 (14,154 cases)	28	4	61	7
1933 (9,757 cases)	35	7	55	3
1934 (36,242 cases)	13	9	74	4
1935 (12,712 cases)	11	10	73	6
1936 (28,562 cases)	16	7	67	10
1937 (17,567 cases)	22	4	68	6
1938 (21,462 cases)	21	4	70	5
1939 (24,357 cases)	14	13	66	7
1940 (13,809 cases)	23	8	59	10
1941 (24,876 cases)	37	7	52	4
1942 (21,085 cases)	22	7	66	5
1943 (13,412 cases)	5	13	67	15
1944 (13,083 cases)	15	15	32	38
1945 (9,899 cases)	46	11	37	6
1946 (12,511 cases)	13	12	72	3
1947 (10,849 cases)	15	12	56	17
1948 (13,181 cases)	12	16	60	12
1949 (9,268 cases)	39	6	48	7
1950 (27,286 cases)	3	19	71	6
1951 (24,405 cases)	41	9	31	13
1952 (29,492 cases)	28	19	46	4
1953 (18,163 cases)	23	22	46	9

Table II.—Nass River Sockeyes, 1953, Grouped by Age, Sex, Length, and by Their Early History

Length in Inches	Number of Individuals																Total
	3_1		4_1		4_2		5_2		6_2		4_3		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
19																	
19¼																	
19½																	
19¾		1															1
20												1					1
20¼																	
20½					1	1											2
20¾																	
21						3											3
21¼					1	1											2
21½	1				2	9							1				13
21¾					2	8							1	1			12
22				1	3	26		1						5			36
22¼					1	9								1			11
22½				1	8	21		2					3	14			49
22¾					4	14							2	8			28
23					18	38		2					10	48			116
23¼				1	4	6								12			23
23½				2	25	22		2					15	45			111
23¾				2	15	12		5					17	24			75
24			1	1	29	12	2	5					40	98	2	1	191
24¼				1	4	3		1					5	8			22
24½				1	28	5	2	10					36	47		3	132
24¾					10	2	2	12					24	25		1	76
25			2		29	1	6	33					78	42	3	7	201
25¼							2	11					7	6		1	27
25½			2		5	1	7	21					41	15		4	96
25¾							3	14					21	4		2	44
26					3		23	39					33	6	5	5	114
26¼							3	2					3	2	1	1	12
26½				1			16	15					9	3	1	2	47
26¾							12	7					6		2	3	30
27							16	16					5	1	13	10	61
27¼							5	2						1	2	1	11
27½							24	1					1		9	4	39
27¾							10								5	2	17
28							14	2							17	6	39
28¼							2								3		5
28½							6			1					9	3	19
28¾							2	1							6	1	10
29							3								10		13
29¼							1										1
29½															1		1
29¾															1		1
30																	
30¼															1		1
30½															1		1
30¾																	
Totals	1	1	5	11	192	194	161	204		1		1	358	416	92	57	1,694
Average lengths	21.5	19.8	25.0	23.8	23.9	22.9	26.9	25.6		28.5		20.0	24.9	24.1	27.7	26.5	24.8

Table III.—Nass River Sockeyes, 1953, Grouped by Age, Sex, Weight, and by Their Early History

Weight in Pounds	Number of Individuals																Total
	3_1		4_1		4_2		5_2		6_2		4_3		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
2																	
2¼																	
2½		1															1
2¾																	
3						1						1					2
3¼														1			1
3½														1			1
3¾						1							1	1			3
4					3	6								1			10
4¼	1					3		1					1	7			13
4½				1	3	11		1					2	16			34
4¾				1	2	14							5	16			38
5				2	12	43		1					9	35			102
5¼				1	6	14		1					9	52	1		84
5½				4	20	33		6					34	63		2	162
5¾					24	18		3					16	44			105
6					22	24	6	12					40	53	1	2	160
6¼			3	1	20	11		12					27	35		1	110
6½					27	10	5	15					54	33	1	2	147
6¾			2		11	2	6	14					27	8	2	2	74
7					23	3	12	33					50	25	2	6	154
7¼					6		3	18					16	8	1	4	56
7½					5		14	27					25	9	2	4	86
7¾					3		7	14					13	3	2	1	43
8					5		23	20					18	4	7	12	89
8¼				1			12	4					4	1	7	2	31
8½							12	9					5		9	4	39
8¾							9	5							8	3	25
9							19	1					2		9	3	34
9¼							11	2		1					4	4	22
9½							9	4							8	2	23
9¾							2								5	1	8
10							5	1							5	1	12
10¼							4								7		11
10½							1								2	1	4
10¾															2		2
11															5		5
11¼																	
11½															2		2
11¾																	
12							1										1
12¼																	
12½																	
12¾																	
Totals	1	1	5	11	192	194	161	204		1		1	358	416	92	57	1,694
Average weights	4.3	2.5	6.5	5.5	6.2	5.4	8.3	7.2		9.2		3.0	6.6	5.8	9.0	7.9	6.6

Table IV.—Nass River Sockeyes, Average Lengths in Inches of Principal Age-groups, 1912 to 1953

Year	4_2		5_2		5_3		6_3	
	M.	F.	M.	F.	M.	F.	M.	F.
1912–41	24.5	23.7	26.3	25.2	26.1	25.3	27.7	26.4
1912–41 (conversion)	23.8	23.0	25.6	24.5	25.4	24.6	27.0	25.7
1942	23.9	23.2	26.1	24.9	24.9	24.3	26.9	26.0
1943	22.8	22.2	26.1	24.8	24.1	23.5	27.1	25.8
1944	23.5	22.7	25.7	24.6	24.8	23.8	26.8	25.8
1945	23.4	22.8	25.0	24.4	24.7	24.0	25.1	25.5
1946	23.4	22.4	26.3	24.9	24.9	23.9	28.1	26.0
1947	23.4	22.9	25.9	24.1	24.5	23.6	27.0	25.6
1948	23.3	22.6	26.2	25.3	25.0	24.1	27.7	26.7
1949	23.8	22.8	26.2	23.8	24.7	23.7	26.1	25.5
1950	23.6	23.1	26.0	24.7	24.5	23.7	26.7	25.6
1951	24.0	23.1	26.2	24.8	25.1	24.1	27.4	26.4
1952	23.9	23.1	26.8	25.3	24.8	23.9	27.6	26.3
1953	23.9	22.9	26.9	25.6	24.9	24.1	27.7	26.5

Table V.—Nass River Sockeyes, Average Weights in Pounds of Principal Age-groups, 1914 to 1953

Year	4_2		5_2		5_3		6_3	
	M.	F.	M.	F.	M.	F.	M.	F.
1914–41	6.0	5.4	7.3	6.4	6.9	6.2	8.0	7.0
1942	5.8	5.1	7.1	6.3	6.2	5.6	7.5	6.7
1943	5.2	4.7	7.6	6.4	5.9	5.3	7.9	6.9
1944	5.7	5.0	7.7	6.5	6.7	5.7	8.2	7.1
1945	5.7	5.3	7.0	6.4	6.5	5.9	7.2	7.1
1946	5.6	4.9	8.1	6.7	6.5	5.4	8.9	7.0
1947	5.8	5.3	7.7	6.2	6.3	5.6	8.1	6.9
1948	5.8	5.3	8.1	7.1	7.0	6.0	9.1	7.9
1949	5.9	5.1	7.9	5.8	6.5	5.4	7.7	6.8
1950	5.9	5.2	7.9	6.6	6.4	5.5	8.2	7.1
1951	6.0	5.2	7.9	6.6	6.7	5.7	8.8	7.6
1952	6.0	5.2	8.4	6.9	6.7	5.7	8.7	7.5
1953	6.2	5.4	8.3	7.2	6.6	5.8	9.0	7.9

Table VI.—Nass River Sockeyes, Percentages of Males and Females, 1915 to 1953

Year	4_2		5_2		5_3		6_3		Per Cent Total Males	Per Cent Total Females
	M.	F.	M.	F.	M.	F.	M.	F.		
1915–41 (average)	49	51	47	53	45	55	63	37	47	53
1942	42	58	48	52	44	56	70	30	45	55
1943	51	49	67	33	47	53	74	26	54	46
1944	53	47	45	55	39	61	60	40	50	50
1945	37	63	37	63	38	62	53	47	38	62
1946	62	38	59	41	45	55	75	25	50	50
1947	50	50	52	48	51	49	81	19	56	44
1948	45	55	54	46	52	48	66	34	53	47
1949	57	43	56	44	51	49	50	50	53	47
1950	41	59	42	58	43	57	58	42	44	56
1951	46	54	47	53	46	54	70	30	49	51
1952	49	51	56	44	49	51	59	41	50	50
1953	50	50	44	56	46	54	62	38	48	52

Table VII.—Skeena River Sockeyes, Percentages of Age-groups in Runs of Successive Years and Packs

Year	Percentage of Individuals			
	4_2	5_2	5_3	6_3
1907 (108,413 cases)	—	—	—	—
1908 (139,846 cases)	—	—	—	—
1909 (87,901 cases)	—	—	—	—
1910 (187,246 cases)	—	—	—	—
1911 (131,066 cases)	—	—	—	—
1912 (92,498 cases)	57	43	—	—
1913 (52,927 cases)	50	50	—	—
1914 (130,166 cases)	25	75	—	—
1915 (116,553 cases)	36	64	—	—
1916 (60,923 cases)	34	38	13	18
1917 (65,760 cases)	57	29	9	5
1918 (123,322 cases)	51	34	9	6
1919 (184,945 cases)	27	60	9	4
1920 (90,869 cases)	15	71	6	8
1921 (41,018 cases)	69	22	6	3
1922 (96,277 cases)	70	16	12	2
1923 (131,731 cases)	56	29	8	7
1924 (144,747 cases)	23	69	7	1
1925 (77,784 cases)	51	45	3	1
1926 (82,360 cases)	62	26	9	3
1927 (83,996 cases)	62	28	9	1
1928 (34,559 cases)	51	39	7	3
1929 (78,017 cases)	62	30	6	2
1930 (132,372 cases)	39	52	8	1
1931 (93,023 cases)	40	30	28	2
1932 (59,916 cases)	44	37	7	12
1933 (30,506 cases)	57	36	5	2
1934 (54,558 cases)	58	34	7	1
1935 (52,879 cases)	49	31	18	2
1936 (81,973 cases)	67	20	11	2
1937 (42,491 cases)	45	40	11	4
1938 (47,257 cases)	64	15	16	5
1939 (68,485 cases)	50	35	11	4
1940 (116,507 cases)	80	15	4	1
1941 (81,767 cases)	39	52	8	1
1942 (34,544 cases)	36	54	7	3
1943 (28,268 cases)	39	39	16	6
1944 (68,197 cases)	37	52	7	4
1945 (104,279 cases)	20	63	12	5
1946 (52,928 cases)	13	70	8	9
1947 (32,534 cases)	14	82	3	1
1948 (101,267 cases)	80	13	6	1
1949 (65,937 cases)	17	76	4	3
1950 (47,479 cases)	21	72	4	3
1951 (61,694 cases)	33	61	4	1
1952 (114,775 cases)	66	26	3	5
1953 (65,003 cases)	48	43	6	3

Table VIII.—Skeena River Sockeyes, 1953, Grouped by Age, Sex, Length, and by Their Early Life-history

Length in Inches	Number of Individuals										Total
	3_2		4_2		5_2		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
14	1	—	—	—	—	—	—	—	—	—	1
14¼	—	—	—	—	—	—	—	—	—	—	—
14½	—	—	—	—	—	—	—	—	—	—	—
14¾	—	—	—	—	—	—	—	—	—	—	—
15	—	—	—	—	—	—	—	—	—	—	—
15¼	—	—	—	—	—	—	—	—	—	—	—
15½	—	—	—	—	—	—	—	—	—	—	—
15¾	—	—	—	—	—	—	—	—	—	—	—
16	—	—	—	—	—	—	—	—	—	—	—
16¼	—	—	—	—	—	—	—	—	—	—	—
16½	—	—	—	—	—	—	—	—	—	—	—
16¾	—	—	—	—	—	—	—	—	—	—	—
17	1	—	—	—	—	—	—	—	—	—	1
17¼	—	—	—	—	—	—	—	—	—	—	—
17½	—	—	—	—	—	—	—	—	—	—	—
17¾	—	—	—	—	—	—	—	—	—	—	—
18	—	—	—	—	—	—	—	—	—	—	—
18¼	—	—	—	—	—	—	—	—	—	—	—
18½	—	—	—	—	—	—	—	—	—	—	—
18¾	—	—	—	—	—	—	—	—	—	—	—
19	—	—	—	—	—	—	—	—	—	—	—
19¼	—	—	—	—	—	—	—	—	—	—	—
19½	—	—	—	—	—	—	—	—	—	—	—
19¾	—	—	—	1	—	—	—	—	—	—	1
20	—	—	1	—	—	—	—	—	—	—	1
20¼	—	—	1	—	—	—	1	—	—	—	2
20½	—	—	9	1	—	—	—	—	—	—	10
20¾	—	—	6	2	—	—	—	—	—	—	8
21	—	—	17	3	—	—	—	—	—	—	20
21¼	—	—	13	4	—	—	1	1	—	—	19
21½	—	—	14	24	1	—	1	2	—	—	42
21¾	—	—	5	33	—	—	1	1	—	—	40
22	—	—	18	48	—	1	4	7	1	—	79
22¼	—	—	18	56	1	—	4	6	—	—	85
22½	—	—	20	69	1	—	2	7	—	—	99
22¾	—	—	18	83	1	4	3	6	—	—	115
23	—	—	29	78	2	6	8	4	—	—	127
23¼	—	—	32	69	—	9	11	6	1	1	129
23½	—	—	45	42	1	14	6	5	—	—	113
23¾	—	—	29	32	—	22	12	2	—	1	98
24	—	—	35	26	6	33	4	1	3	2	110
24¼	—	—	34	17	7	43	4	2	—	1	108
24½	—	—	27	10	7	64	3	1	—	4	116
24¾	—	—	20	3	12	51	2	—	1	—	89
25	—	—	13	3	10	82	2	—	—	2	112
25¼	—	—	5	—	16	66	3	1	1	3	95
25½	—	—	3	1	13	65	1	—	3	—	86
25¾	—	—	—	1	28	50	1	—	7	—	87
26	—	—	—	—	36	40	1	—	3	3	83
26¼	—	—	—	—	29	12	1	—	5	—	47
26½	—	—	1	—	33	16	—	1	1	4	56
26¾	—	—	—	—	26	9	2	—	2	2	41
27	—	—	—	—	24	7	—	—	1	—	32
27¼	—	—	—	—	18	3	—	—	—	—	21
27½	—	—	—	—	14	3	—	—	3	1	21
27¾	—	—	—	—	6	1	—	—	—	—	7
28	—	—	—	—	5	—	—	—	1	2	8
28¼	—	—	—	—	5	—	—	—	1	—	6
28½	—	—	—	—	2	—	—	—	—	—	2
28¾	—	—	—	—	2	—	—	—	—	—	2
29	—	—	—	—	1	—	—	—	—	—	1
29¼	—	—	—	—	—	—	—	—	1	—	1
Totals	2	—	413	606	307	601	78	53	35	26	2,121
Average lengths	15.5	—	23.2	22.8	26.2	25.0	23.6	22.9	26.0	25.5	24.1

Table IX.—Skeena River Sockeyes, 1953, Grouped by Age, Sex, Weight, and by Their Early History

Weight in Pounds	Number of Individuals										Total
	3_2		4_2		5_2		5_3		6_2		
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
1											
1¼											
1½	1										1
1¾											
2											
2¼	1										1
2½											
2¾											
3											
3¼											
3½			5	2			1	2			10
3¾			4	2			1				7
4			28	14		1	4				47
4¼			14	26	1	1		2			44
4½			26	58	1	2	5	13	1		106
4¾			16	41		1	6	4			68
5			27	83	3	9	5	11	1		139
5¼			22	55	3	15	4	2	1	2	104
5½			41	98	4	41	6	4		1	195
5¾			24	43	6	26	8	6	1	1	115
6			32	73	6	49	5	5	1	2	173
6¼			28	34	7	32	9	1		2	113
6½			32	33	8	66	9	1	1	1	151
6¾			18	14	13	41	4		2	1	93
7			38	16	19	74	4	1	2	1	155
7¼			17	5	14	29			2	4	71
7½			21	6	40	66	1		4	1	139
7¾			6	2	15	40			3		66
8			10	1	38	46	4		4	4	107
8¼			2		19	18	1	1	1		42
8½			1		23	22			3	1	50
8¾					15	6	1		1		23
9			1		19	9			2	2	33
9¼					8	1			1		10
9½					13	4			1	2	20
9¾					9				1	1	11
10					10	1					11
10¼					2						2
10½					4	1					5
10¾					1				1		2
11					2						2
11¼					1				1		2
11½					2						2
11¾					1						1
12											
12¼											
Totals	2		413	606	307	601	78	53	35	26	2,121
Average weights	1.9		5.8	5.5	8.0	6.9	5.8	5.2	7.8	7.3	6.4

Table X.—Skeena River Sockeyes, Average Lengths in Inches of Principal Age-groups, 1912 to 1953

Year	4_2		5_2		5_3		6_3	
	M.	F.	M.	F.	M.	F.	M.	F.
1912–41	23.7	23.1	25.8	24.9	24.2	23.4	25.8	24.8
1912–41 (conversion)	23.0	22.4	25.1	24.2	23.5	22.7	25.1	24.1
1942	22.6	22.3	25.2	24.3	24.1	23.7	26.3	24.9
1943	21.9	21.9	25.1	23.9	23.3	22.6	25.8	24.7
1944	22.4	21.7	24.8	23.9	22.5	21.7	25.0	23.7
1945	22.6	22.3	24.9	24.1	23.3	22.6	25.0	24.3
1946	22.7	22.0	25.4	24.3	23.9	23.2	25.5	24.4
1947	22.3	22.0	25.1	23.8	23.0	22.4	26.3	25.8
1948	23.0	22.3	25.3	24.1	23.0	22.1	26.0	24.5
1949	22.5	22.2	25.3	24.5	23.2	22.3	24.8	23.9
1950	22.8	22.3	25.7	24.4	23.9	23.4	25.5	24.3
1951	22.7	22.6	25.9	24.8	23.6	22.9	26.0	24.6
1952	23.3	22.6	25.8	24.7	23.2	22.8	26.1	24.6
1953	23.2	22.8	26.2	25.0	23.6	22.9	26.0	25.5

Table XI.—Skeena River Sockeyes, Average Weights in Pounds of Principal Age-groups, 1914 to 1953

Year	4_2		5_2		5_3		6_3	
	M.	F.	M.	F.	M.	F.	M.	F.
1914–41	5.4	5.0	6.8	6.1	5.7	5.1	6.8	6.0
1942	4.9	4.7	6.7	6.0	5.8	5.4	7.2	6.6
1943	4.7	4.6	6.8	5.9	5.5	4.9	7.3	6.1
1944	5.1	4.6	7.0	6.1	5.3	4.6	7.1	5.8
1945	5.2	4.9	6.7	6.1	5.6	5.0	6.7	6.2
1946	4.7	4.2	6.9	5.8	5.8	5.1	7.0	6.1
1947	4.9	4.7	6.9	5.9	5.3	5.0	7.7	6.8
1948	5.5	4.9	7.3	6.1	5.4	4.7	7.7	6.4
1949	5.0	4.7	7.1	6.3	5.3	4.8	6.6	5.7
1950	4.8	4.3	7.2	5.9	5.8	5.1	6.8	5.6
1951	5.1	5.0	7.6	6.5	5.6	5.0	7.6	6.4
1952	5.6	5.0	7.5	6.4	5.6	5.0	7.4	6.0
1953	5.8	5.5	8.0	6.9	5.8	5.2	7.8	7.3

Table XII.—Skeena River Sockeyes, Percentages of Males and Females, 1915 to 1953

Year	4_2		5_2		Per Cent Total Males	Per Cent Total Females
	M.	F.	M.	F.		
1915–41 (average)	48	52	43	57	46	54
1942	42	58	25	75	33	67
1943	50	50	31	69	43	57
1944	54	46	34	66	43	57
1945	41	59	35	65	38	62
1946	50	50	32	68	38	62
1947	50	50	29	71	33	67
1948	50	50	29	71	47	53
1949	54	46	30	70	36	64
1950	56	44	40	60	44	56
1951	41	59	37	63	39	61
1952	52	48	34	66	48	52
1953	40	60	34	66	39	61

Table XIII.—Rivers Inlet Sockeyes, Percentages of Age-groups in Runs of Successive Years and Packs

Year	Percentage of Individuals			
	4_2	5_2	5_3	6_3
1907 (87,874 cases)	—	—	—	—
1908 (64,652 cases)	—	—	—	—
1909 (89,027 cases)	—	—	—	—
1910 (126,921 cases)	—	—	—	—
1911 (88,763 cases)	—	—	—	—
1912 (112,884 cases)	21	79	—	—
1913 (61,745 cases)	80	20	—	—
1914 (89,890 cases)	35	65	—	—
1915 (130,350 cases)	13	87	—	—
1916 (44,936 cases)	26	74	—	—
1917 (61,195 cases)	39	61	—	—
1918 (53,401 cases)	57	43	—	—
1919 (56,258 cases)	46	54	—	—
1920 (121,254 cases)	5	95	—	—
1921 (46,300 cases)	49	51	—	—
1922 (60,700 cases)	81	18	1	—
1923 (107,174 cases)	74	24	2	—
1924 (94,891 cases)	43	54	2	1
1925 (159,554 cases)	23	77	—	—
1926 (65,581 cases)	59	38	2	1
1927 (64,461 cases)	81	16	3	—
1928 (60,044 cases)	55	40	4	1
1929 (70,260 cases)	77	18	3	2
1930 (119,170 cases)	49	48	2	1
1931 (76,428 cases)	53	44	2	1
1932 (69,732 cases)	67	27	5	1
1933 (83,507 cases)	44	55	1	—
1934 (76,923 cases)	77	20	2	1
1935 (135,038 cases)	57	41	1	1
1936 (46,351 cases)	53	46	1	—
1937 (84,832 cases)	60	37	3	—
1938 (87,942 cases)	27	70	1	2
1939 (54,143 cases)	67	32	1	—
1940 (63,469 cases)	69	28	3	—
1941 (93,378 cases)	59	40	1	—
1942 (79,199 cases)	8	91	—	1
1943 (47,602 cases)	8	91	—	1
1944 (36,852 cases)	76	23	1	—
1945 (89,735 cases)	57	41	2	—
1946 (73,320 cases)	37	63	—	—
1947 (140,087 cases)	3	97	—	—
1948 (37,665 cases)	55	44	1	—
1949 (39,495 cases)	84	14	1	—
1950 (142,710 cases)	13	87	(1)	—
1951 (102,565 cases)	38	60	1	1
1952 (84,298 cases)	41	58	1	(1)
1953 (132,925 cases)	73	26	1	(1)

[1] Age-class represented but less than 0.5 per cent.

Table XIV.—Rivers Inlet Sockeyes, 1953, Grouped by Age, Sex, Length, and by Their Early History

Length in Inches	Number of Individuals								Total
	4_2		5_2		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	
17	—	—	—	—	—	—	—	—	—
17¼	—	—	—	—	—	—	—	—	—
17½	—	—	—	—	—	—	—	—	—
17¾	—	—	—	—	—	—	—	—	—
18	—	—	—	—	1	—	—	—	1
18¼	—	—	—	—	—	—	—	—	—
18½	—	—	—	—	—	—	—	—	—
18¾	2	—	—	—	—	—	—	—	2
19	2	—	—	—	—	—	—	—	2
19¼	3	—	—	—	—	—	—	—	3
19½	20	3	—	—	—	—	—	—	23
19¾	18	1	—	—	—	—	—	—	19
20	32	3	—	—	—	—	—	—	35
20¼	51	12	—	—	—	—	—	—	63
20½	64	22	—	—	—	1	—	—	87
20¾	58	45	—	—	—	—	—	—	103
21	70	58	—	—	—	—	—	—	128
21¼	72	80	—	—	—	1	—	—	153
21½	61	68	—	—	—	—	—	—	129
21¾	56	68	—	2	2	—	—	—	128
22	54	78	—	1	—	—	—	—	133
22¼	48	64	—	—	1	—	—	—	113
22½	28	54	—	1	—	2	—	—	85
22¾	37	39	—	5	—	1	—	—	82
23	31	21	3	4	—	—	—	—	59
23¼	30	21	1	8	—	—	—	—	60
23½	26	13	7	13	—	—	—	—	59
23¾	18	7	3	11	1	—	—	—	40
24	9	3	5	15	—	—	—	—	32
24¼	8	—	3	13	—	—	—	—	24
24½	6	1	3	19	—	—	—	—	29
24¾	6	—	2	17	—	—	—	—	25
25	2	—	4	23	1	—	—	—	30
25¼	—	—	3	28	—	—	—	1	32
25½	—	—	5	39	—	—	—	—	44
25¾	—	—	7	37	—	—	—	—	44
26	—	—	9	28	—	—	—	—	37
26¼	—	—	12	35	—	—	—	1	48
26½	—	—	13	24	—	—	—	—	37
26¾	—	—	17	13	—	—	—	—	30
27	—	—	10	6	—	—	—	—	16
27¼	—	—	13	9	—	—	—	—	22
27½	—	—	13	2	—	—	—	—	15
27¾	—	—	9	—	—	—	—	—	9
28	—	—	19	2	—	—	—	—	21
28¼	—	—	6	—	—	—	—	—	6
28½	—	—	7	—	—	—	—	—	7
28¾	—	—	1	—	—	—	—	—	1
29	—	—	2	—	—	—	—	—	2
29¼	—	—	—	—	—	—	—	—	—
29½	—	—	—	—	—	—	—	—	—
29¾	—	—	1	—	—	—	—	—	1
Totals	812	661	178	355	6	5	—	2	2,019
Average lengths	21.6	21.8	26.5	25.3	22.1	21.9	—	25.8	22.8

Table XV.—Rivers Inlet Sockeyes, 1953, Grouped by Age, Sex, Weight, and by Their Early History

Weight in Pounds	Number of Individuals								Total
	4_2		5_2		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	
2									
2¼									
2½									
2¾									
3	7				1				1
3¼	10	2							7
3½	38	7							12
3¾	49	20							45
4	105	77							69
4¼	85	85		1	1	1			183
4½	132	147	1	2					172
4¾	73	86		2		2			282
5	83	96	1	3	1	1			163
5¼	45	37	2	8					185
5½	63	56	2	7	1	1			92
5¾	28	22	1	8					130
6	39	21	6	12					59
6¼	13	1	4	15	1				78
6½	18	2	10	23					34
6¾	11	1	1	12					53
7	11	1	6	27					25
7¼	1		6	19					45
7½	1			36	1				26
7¾			8	21					38
8			5	43					29
8¼			5	23					48
8½			14	29					28
8¾			6	12				1	44
9			12	29					18
9¼			11	8					41
9½			15	9					19
9¾			12	3					24
10			11	2					15
10¼			10	1				1	14
10½			8						11
10¾			10						8
11			4						10
11¼			1						4
11½			3						1
11¾			1						3
12			1						1
12¼									1
12½									
12¾									
13			1						
13¼									1
13½									
13¾									
Totals	812	661	178	355	6	5	—	2	2,019
Average weights	4.7	4.7	8.8	7.6	5.2	4.8	—	9.2	5.6

Table XVI.—Rivers Inlet Sockeyes, Average Lengths in Inches of the 4_2 and 5_2 Groups, 1912 to 1953

Year	4_2		5_2	
	M.	F.	M.	F.
912–41	22.4	22.4	25.4	24.7
912–41 (conversion)	21.6	21.6	24.6	23.9
942	21.9	21.3	25.0	23.8
943	20.5	21.1	24.3	23.7
944	21.1	21.0	23.5	23.3
945	20.9	21.2	24.2	23.9
946	20.6	21.1	25.1	24.1
947	20.6	20.7	24.0	23.5
948	21.4	21.3	25.2	24.2
949	20.9	21.4	23.8	22.8
950	21.1	20.8	25.2	24.2
951	21.9	21.9	25.8	24.8
952	21.5	21.5	26.0	25.0
953	21.6	21.8	26.5	25.3

Table XVII.—Rivers Inlet Sockeyes, Average Weights in Pounds of the 4_2 and 5_2 Groups, 1914 to 1953

Year	4_2		5_2	
	M.	F.	M.	F.
914–41	4.9	4.8	7.0	6.5
942	5.1	4.6	7.2	6.4
943	4.1	4.4	6.8	6.3
944	4.6	4.4	6.2	6.0
945	4.3	4.4	6.6	6.4
946	3.9	3.9	7.2	6.2
947	4.1	3.9	6.4	5.9
948	4.7	4.6	7.9	7.0
949	4.4	4.3	5.9	5.9
950	4.2	3.9	7.5	6.4
951	5.2	5.0	8.6	7.4
952	4.9	4.7	8.7	7.4
953	4.7	4.7	8.8	7.6

Table XVIII.—Rivers Inlet Sockeyes, Percentages of Males and Females, 1915 to 1953

Year	4_1		4_2		5_2		Per Cent Total Males	Per Cent Total Females
	M.	F.	M.	F.	M.	F.		
915–41 (average)	—	—	63	37	34	66	50	50
942	—	—	61	39	35	65	38	62
943	—	—	62	38	34	66	36	64
944	—	—	67	33	33	67	59	41
945	—	—	70	30	39	61	57	43
946	—	—	79	21	37	63	53	47
947	—	—	72	28	35	65	36	64
948	—	—	50	50	38	62	45	55
949	36	64	70	30	22	78	63	37
950	50	50	75	25	36	64	41	59
951	—	—	66	34	30	70	44	56
952	—	—	58	42	34	66	44	56
953	—	—	55	45	33	67	49	51

Table XIX.—Smith Inlet Sockeyes, Percentages of Age-groups in Runs of Successive Years and Packs

Year	Percentage of Individuals				
	4_1	4_2	5_2	6_2	5_3
1925 (33,764 cases)	—	—	—	—	—
1926 (17,921 cases)	—	—	—	—	—
1927 (22,682 cases)	—	—	—	—	—
1928 (33,442 cases)	—	—	—	—	—
1929 (9,683 cases)	—	—	—	—	—
1930 (32,057 cases)	—	—	—	—	—
1931 (12,867 cases)	—	—	—	—	—
1932 (25,488 cases)	—	—	—	—	—
1933 (37,369 cases)	—	—	—	—	—
1934 (14,607 cases)	—	—	—	—	—
1935 (31,648 cases)	—	—	—	—	—
1936 (12,788 cases)	—	—	—	—	—
1937 (25,258 cases)	—	—	—	—	—
1938 (33,894 cases)	—	—	—	—	—
1939 (17,833 cases)	—	—	—	—	—
1940 (25,947 cases)	—	—	—	—	—
1941 (21,495 cases)	—	—	—	—	—
1942 (15,939 cases)	—	—	—	—	—
1943 (15,010 cases)	—	—	—	—	—
1944 (3,165 cases)	—	—	—	—	—
1945 (15,014 cases)	—	50	50	—	—
1946 (14,318 cases)	—	11	89	—	—
1947 (36,800 cases)	—	5	95	—	—
1948 (10,456 cases)	—	7	90	3	—
1949 (13,189 cases)	2	92	5	—	(1)
1950 (42,435 cases)	—	17	83	—	(1)
1951 (49,473 cases)	—	22	77	(1)	(1)
1952 (34,834 cases)	—	8	91	(1)	1
1953 (29,947 cases)	—	89	10	1	(1)

[1] This age-class was represented by less than 0.5 per cent of the number of fish in the sample.

Table XX.—Smith Inlet Sockeyes, 1953, Grouped by Age, Sex, Length, and by Their Early History

Length in Inches	Number of Individuals														Total
	3_1		4_1		3_2		4_2		5_2		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
16															
16¼															
16½															
16¾					1										1
17															
17¼															
17½															
17¾															
18															
18¼															
18½															
18¾															
19															
19¼															
19½															
19¾							1	1							2
20								1							1
20¼							2	1							3
20½							3								3
20¾								6							6
21							10	10							20
21¼							10	27			1				38
21½							16	30							46
21¾							33	32							65
22							29	44							73
22¼	1						48	77							126
22½							56	61							117
22¾							65	45		1	1				112
23							89	34		2	2				127
23¼							63	18		2		2			85
23½							61	12	1	2					76
23¾							40	10	2	2	1				55
24							50	4		2					56
24¼				1			26	1	1	4					33
24½							9	1	1	5					16
24¾							3		2	3					8
25							1		3	2			1		7
25¼									6	6					12
25½							1		2	12			1		16
25¾							1		3	10					14
26									4	9					13
26¼									1	6			1		8
26½									3	1					4
26¾									2	1					3
27									3	1					4
27¼									1						1
27½									1						1
27¾									3						3
28									1						1
28¼															
28½															
28¾															
Totals	1			1	1		617	415	40	71	5	2	3		1,156
Average lengths	22.3			24.3	16.8		22.9	22.3	25.9	25.2	22.8	23.3	25.6		22.9

Table XXI.—Smith Inlet Sockeyes, 1953, Grouped by Age, Sex, Weight, and by Their Early History

Weight in Pounds	Number of Individuals														Total
	3_1		4_1		3_2		4_2		5_2		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
1															
1¼															
1½															
1¾															
2					1										1
2¼															
2½															
2¾															
3															
3¼															
3½								1							1
3¾							1								1
4							6	2							8
4¼							13	9							22
4½							13	31			1				45
4¾							18	45							63
5							43	69		1					113
5¼							41	66		2					109
5½							101	82	2	1	1				187
5¾							58	38		1	1	1			99
6				1			91	43	2	3	1	1			142
6¼	1						65	19		1					86
6½							72	8	1	5					86
6¾							30	1	1		1				33
7							41	1	3	6					51
7¼							9		2	6			1		18
7½							9		1	2					12
7¾									1	12					13
8							4		7	9					20
8¼									6	3					9
8½							2		2	8			2		14
8¾									2	4					6
9									2	4					6
9¼										1					1
9½										2					2
9¾									2						2
10									2						2
10¼									2						2
10½									1						1
10¾									1						1
11															
11¼															
11½															
11¾															
Totals	1			1	1		617	415	40	71	5	2	3		1,156
Average weights	6.2			5.9	1.9		5.9	5.3	8.2	7.6	5.7	5.8	8.1		5.9

Table XXII.—Smith Inlet Sockeyes, Average Lengths in Inches of Age-groups, 1945 to 1953

Year	4_1		4_2		5_2		6_2		5_3	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
1945	—	—	22.2	22.0	25.1	24.4	—	—	—	—
1946	—	—	21.3	22.7	24.7	24.0	—	—	—	—
1947	—	—	23.2	23.4	25.2	24.3	—	—	—	—
1948	—	—	21.9	21.7	25.0	24.3	26.7	25.0	—	—
1949	25.4	23.5	21.4	21.7	24.6	24.3	—	25.5	—	—
1950	—	—	21.6	21.7	24.8	24.0	—	—	20.5	—
1951	—	—	22.8	22.0	25.6	24.8	—	25.1	23.4	—
1952	—	—	21.8	22.4	25.7	24.9	—	25.1	22.9	23.1
1953	—	24.3	22.9	22.3	25.9	25.2	—	—	22.8	23.3

Table XXIII.—Smith Inlet Sockeyes, Average Weights in Pounds of Age-groups, 1945 to 1953

Year	4_1		4_2		5_2		6_2		5_3	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
1945	—	—	4.9	4.7	7.1	6.5	—	—	—	—
1946	—	—	4.6	5.8	7.3	6.6	—	—	—	—
1947	—	—	5.7	5.5	6.9	6.0	—	—	—	—
1948	—	—	5.1	5.4	7.6	6.9	10.3	7.5	—	—
1949	7.9	6.1	5.0	5.1	7.2	6.7	—	7.3	—	—
1950	—	—	4.9	5.0	7.4	6.6	—	—	4.0	—
1951	—	—	6.0	5.2	8.2	7.3	—	7.2	6.4	—
1952	—	—	4.8	5.2	8.0	7.1	—	7.3	5.7	5.4
1953	—	5.9	5.9	5.3	8.2	7.6	—	—	5.7	5.8

Table XXIV.—Smith Inlet Sockeyes, Percentages of Males and Females, 1945 to 1953

Year	4_1		4_2		5_2		6_2		5_3		Per Cent Total Males	Per Cent Total Females
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.		
1945	—	—	73	27	49	51	—	—	—	—	61	39
1946	—	—	76	24	37	63	—	—	—	—	41	59
1947	—	—	38	62	47	53	—	—	—	—	46	54
1948	—	—	79	21	42	58	11	89	—	—	43	57
1949	36	64	80	20	40	60	—	100	—	—	77	23
1950	—	—	86	14	42	58	—	—	100	—	49	51
1951	—	—	72	28	41	59	—	100	100	—	48	52
1952	—	—	57	43	38	62	—	100	63	37	40	60
1953	—	100	60	40	36	64	—	—	71	29	58	42

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Results of Investigation of the Herring Populations on the West Coast and Lower East Coast of Vancouver Island in 1953-54

BY

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RESULTS OF INVESTIGATION OF THE HERRING POPULATIONS ON THE WEST COAST AND LOWER EAST COAST OF VANCOUVER ISLAND IN 1953–54.

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INTRODUCTION

A long-term investigation of the effectiveness of catch quotas in preventing a decline in abundance from fishing was begun in 1946–47. In that and subsequent seasons, no catch quota restrictions were applied to herring-fishing in the west coast of Vancouver Island sub-district, while a fixed annual quota of 40,000 tons was maintained in the lower east coast of Vancouver Island sub-district. A closing-date for fishing of February 5th was applied to each population. A long-term investigation is required because of complications introduced by natural fluctuations in year-class strength and by the necessity of determining the effects of unrestricted fishing during periods of both high and low levels of abundance.

Abundance on the lower east coast has been high throughout the period of the investigation; on the west coast, abundance was generally high for the first five years. In 1951–52 (the sixth year), population abundance decreased sharply on the west coast, but in 1952–53 and 1953–54 it increased again to a reasonably high level.

The lack of a major reduction fishery in 1952–53, arising from a price dispute between fishing companies and fishermen, has resulted in the loss of the opportunity, for the present, at least, to determine whether, during a period of low population abundance, unrestricted fishing would reduce the spawning stock to a level where recruitment would be affected.

The results of the first seven years of investigation have been presented in an annual series of reports.* In this report, the eighth of the series, the results obtained during the 1953–54 season are presented and compared with those of previous seasons. For the west coast and lower east coast sub-districts, changes in catch, fishing effort, strengths of the year-classes comprising the fishing and spawning runs, and the extent of spawn deposition are discussed. A review of the extent of movement between all major herring populations is presented. Finally, the implications of the results obtained from the comparative study of the two populations subject to different methods of management are considered.

Research on the Pacific herring (*Clupea pallasi*) is carried out at the Pacific Biological Station, Nanaimo, B.C., by the Fisheries Research Board of Canada. Although results pertaining to only two populations are contained in this report, all major herring populations in British Columbia are studied. An investigation to determine the relationship between the abundance of juvenile (I-year) herring and year-class strength at recruitment is in progress.

Figure 1 is a map of Southern British Columbia showing the statistical areas into which the west coast and lower east coast sub-districts are divided, together with some of the place-names mentioned in the text and in the supplementary tables.

THE 1953–54 FISHERY

The 1953–54 herring-fishing season opened with a small summer fishery in the middle east coast, lower east coast, and west coast of Vancouver Island sub-districts. The summer fishery in the middle east coast was the most extensive: 325 tons were taken in June in Area 16, 681 tons in July in Areas 14 and 16, 1,747 tons in August almost entirely in Area 14, and 5,850 tons in September in Area 14. A total of eighteen seines fished Area 14 during the latter half of September, compared with three to six in the earlier part of the season. In the lower east coast sub-district, 104 tons were taken in May and 115 tons in June and July in Area 17A by one seine. On the west coast, 1,000 tons were taken off Swiftsure Bank (Area 21), principally during the first two weeks of July. Ten seiners fished during this period, with one continuing until the end of the month.

During the last week in September and the first week of October, Areas 19 and 20 were scouted by eight seines. A small catch of 250 tons was taken in Area 19 off Albert Head and William Head. The main lower east coast fishery began during the week of October 11–16, with fair fishing (69.2 tons per seine-day) being experienced by nine seines in Nanoose Bay (Area 17A) and somewhat lighter fishing (47.4 tons per seine-day) by twenty-three seines in Trincomali Channel (Area 17B). During the next two weeks fishing was poor in Nanoose Bay, but excellent catches were made off Porlier Pass (Area 17B) and in Swanson Channel (Area 18). The quota was taken by November 2nd: a total of fifty-six seines participated. Normally, to fulfill the requirements of the comparative study of the lower east coast and west coast populations, a rigid quota of 40,000 tons is maintained in the lower east coast sub-district. However, since it was considered possible that the almost complete lack of a fishery in 1952–53 might have resulted in a larger than normal carry-over of fish, quota extensions of 10,000 tons for reduction purposes and 5,000 tons for special purposes were granted. Fishing recom-

* Previous publications in this series are Tester and Stevenson, 1947, 1948; Stevenson, 1950; Stevenson and Kask, 1952; Stevenson, Hourston, and Lanigan, 1951; Stevenson, Hourston, Jackson, and Outram, 1952; Stevenson and Outram, 1953.

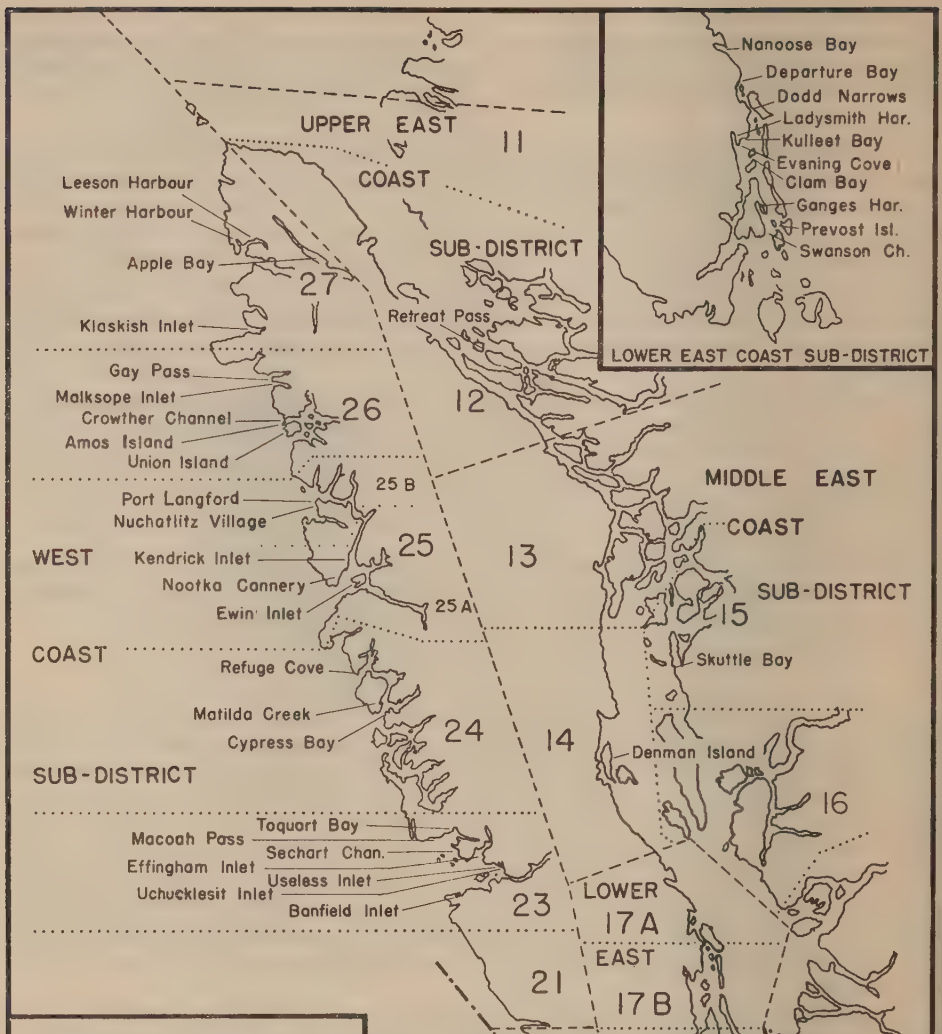

Fig. 1. Map showing the statistical areas into which the sub-districts of the Southern British Columbia coast are divided, and including some of the place-names mentioned in the text and supplementary tables.

menced on November 10th, and by November 12th the 10,000-ton extension was taken. The whole fleet of fifty-six seines took part, and the fishery was again centred off Porlier Pass and in Swanson Channel. Fishing continued until December 10th for the special-purposes quota, with each company providing one boat. Catches were small and the quota was not attained, due probably to a lack of demand rather than to a scarcity of fish. The scanty data available indicated that catch per unit of effort was comparable to that during the regular fishery. Details of catch, fishing effort, and catch per unit of effort are given for each area and for the whole lower east coast sub-district in Table I. The information on fishing effort and catch per unit of effort is obtained from pilot-house record-books, in which seine-boat captains record their catches and the number of fishing and scouting days. These records represented 82 per cent of the total catch for the sub-district; the total fishing effort was gained by adjusting the number of recorded fishing-days to account for the total catch.

After the close of the lower east coast fishery, sixteen seines commenced fishing on the west coast of Vancouver Island in Barkley Sound (Area 23) on November 15th. In the ensuing week, good catches were made in Area 23 in Effingham and Uchucklesit Inlets. During this week, two boats fished Sydney Inlet (Area 24) and took 500 tons. Steady but unspectacular fishing continued in Barkley Sound until the Christmas recess on December 18th, producing a total of 21,500 tons. During the week of December 13–18, 2,500 tons were taken in Clayoquot Sound (Area 24).

Fishing recommenced on January 6th. Throughout the west coast sub-district fishing was poor, particularly after the onset of freezing weather conditions in the middle of January. With the resumption of fishing, the boats concentrated in Area 23 and to a lesser extent in Area 25. Small catches were made in Barkley Sound (Area 23), Sydney Inlet (Area 24), Tahsis Inlet and Nootka Sound (Area 25), and in Quatsino Sound (Area 27). By the end of the week, the boats in Area 23 had dispersed to other areas on the west coast. During the following week, the majority of the vessels concentrated in Areas 25 and 26, and to a lesser extent in Area 24. Most of the boats that had fished Area 27 in the previous week moved to the central sub-district. Catches were made in Barkley Sound (Area 23), Sydney Inlet (Area 24), Tahsis Inlet and Nootka Sound (Area 25), and in Ououkinsh and Malksope Inlets (Area 26). During the week of January 17–22, freezing weather curtailed fishing. Small catches were made in Barkley Sound (Area 23), Sydney Inlet (Area 24), Esperanza Inlet (Area 25), Nasparti and Ououkinsh Inlets (Area 26), and Quatsino Sound (Area 27), with the majority of the vessels fishing in Area 26. For the remaining two weeks of the season, fishing in all areas, except perhaps Area 27, was poor, and fish were scattered.

Details of catch, fishing effort, and catch per unit of effort are given for each area and for the whole west coast sub-district in Table I. Entries in pilot-house record-books represented 87 per cent of the total catch for the sub-district; the total fishing effort was calculated in the same manner as that for the lower east coast sub-district. Catch, fishing effort, and catch per unit of effort on the west coast of Vancouver Island are tabulated below for the 1953–54 and previous seasons:—

	Season							
	1946–47	1947–48	1948–49	1949–50	1950–51	1951–52	1952–53	1953–54
Catch (tons)	59,000	45,200	55,000	37,300	25,200	30,000	23	41,350
Effort (seine-days)	777	948	686	790	528	395	——	937
Catch per unit of effort (tons per seine per day)	76	48	80	47	48	76	——	44

The 1953–54 west coast fishery produced the largest catch since 1948–49. Of this total, Barkley Sound produced 24,200 tons, 21,500 tons before the Christmas recess and

2,700 tons after; Sydney Inlet (Area 24) yielded 5,350 tons, of which 3,000 tons were taken before the recess. The catch in Area 23 was the largest since 1949–50, and that in Area 24 since 1946–47. Areas 25, 26, and 27 were fished only in the post-Christmas period. The catches in Areas 26 and 27 were the largest since 1942–43. The catch in Area 25 was the poorest since 1949–50.

The average catch per unit of effort appears to be similar to that for most previous years. The figure for 1951–52 is considered to be artificially high and to have resulted from unusually efficient fleet deployment, particularly in Area 23 (Stevenson, Hourston, Jackson, and Outram, 1952). The system of fleet deployment whereby the bulk of the fleet is moved promptly from fishing-grounds where fish are scarce to grounds where fish are more plentiful undoubtedly lays all calculations of catch per unit of effort in recent years open to question. These figures must, therefore, be accepted with caution, and a certain amount of discretion used in their interpretation.

TAGGING AND TAG-RECOVERY

The tagging and tag-recovery programme provides information on the regions occupied by the major populations of herring, and permits a description of the extent of movement between and within populations. In some years, in certain populations, it has also been possible to make rough calculations of the rate of exploitation of the fishery from tag-recoveries. As these calculations depend on the ratio of first-year recoveries in two successive seasons, the lack of a regular fishery in 1952–53 precludes their calculation again in 1953–54.

In 1954, the emphasis of the tagging programme was shifted from the middle east coast, lower east coast, and west coast of Vancouver Island sub-districts to the central, northern, and Queen Charlotte Islands sub-districts. These latter sub-districts were tagged at least as intensively or more intensively than in previous years, while the other sub-districts were tagged less intensively. However, the level of intensity in the middle east coast, lower east coast, and west coast sub-districts is still adequate to provide information on movements between and within populations. Because of delays occasioned by repairs to both tagging-boats, neither the central nor the west coast sub-districts were tagged as heavily as planned. The total number of tags* put out was reduced compared to the number inserted in the two previous years. Methods used in tagging herring and in recovering tags were the same as those employed in previous years (Stevenson and Lanigan, 1950).

During the 1953–54 season tag-detectors were operated at two reduction plants, one in the Gulf of Georgia plant at Steveston, B.C., and the other in the Seal Cove plant at Prince Rupert, B.C. In previous years a detector was operated at the Imperial reduction plant, but because of changes in the method of unloading it was not possible to operate this detector during the 1953–54 season. The installation in the Colonial reduction plant of a new type of detector using an "Alnico" permanent magnet in place of an induction coil was completed too late in the season to be effective.

The percentage efficiency of the induction-type detector in the Gulf of Georgia plant was 51 per cent during the pre-Christmas period, as compared to 80 per cent for the same period of the previous season (1951–52) in which the detector operated. The reduction in efficiency resulted from a series of faults in the electrical and mechanical systems not completely rectified until comparatively late in the season. During the post-Christmas period, the plant operated at infrequent intervals, and the numbers of tags recovered by the detector and by the plant magnets were insufficient to permit a reliable calculation of detector efficiency to be made. The operation of the tag-detector at Seal Cove again proved most unsatisfactory. The fault lay primarily in the site of

* A list of all taggings made in 1954, including information on the date and place of each tagging, will be supplied on request (Supplementary Table I).

he installation leading to mechanical difficulties in the operation of the trap door. No ttempt has been made to calculate the percentage efficiency of this detector, not only ecause of the small number of tags recovered by it, but also because of the poor magnet eturns from this plant. It was considered that greater errors would be introduced by alculating the probable number of tags in the catch on the basis of the data available han would be introduced by omitting all consideration of the Seal Cove recoveries.

The efficiency of various plants in recovering and submitting tags found on magnets nd in plant machinery depends both on the mechanical efficiency of the magnets and on he diligence of plant crews in returning the tags, together with the required information, n recovery. Plant magnet-efficiency tests were conducted in the same manner as in revious years (Stevenson, Hourston, Jackson, and Outram, 1952). A table of the verage 1953–54 efficiency for each plant tested, with its average efficiency in the previous eason of operation (1951–52) in parentheses, is given below:—

Plant	Number of Tests	Average Efficiency
West Coast		
Kildonan	1 ( )	94 ( )
Port Albion	1 ( )	90 ( )
Nootka	0 (1)	(82)
Ceepeecee	0 (2)	(69)
Hecate	0 (1)	(54)
Average		92 (68)
Steveston and Vicinity		
Imperial	3 (7)	94 (86)
Gulf of Georgia	2 (8)	97 (83)
Colonial	2 (3)	92 (83)
Phoenix	2 (5)	92 (94)
North Shore	3 (3)	97 (97)
Average		94 (89)
North and Central British Columbia		
Namu	3 (2)	86 (91)
Butedale	2 (1)	96 (86)
Seal Cove	1 (1)	68 (63)
Port Edward	4 (3)	92 (94)
Average		85 (82)
Grand average		91 (80)

The tests at Namu and Butedale were carried out by officers of the Department of isheries, the remainder by personnel of the Pacific Biological Station. Because of diffiulties in transportation, it was impossible to test the Nootka, Ceepeecee, or Hecate plants. he efficiency of all plants tested was, in general, about the same as in 1951–52. The ight increases in efficiency found in some plants are attributed to the greater interest in g-recovery shown by plant employees.

Recoveries by Tag-detectors

The number of detector recoveries showed a marked decrease compared to the mber recovered in 1951–52. A total of 67 tags were recovered; of these, the Gulf of

Georgia installation yielded 64, the Seal Cove installation, 3. Detector recoveries in 1951–52 amounted to 226 tags from the regular spring tagging, and 20 from taggings carried out at Sooke in 1951 just prior to the opening of the fishery. A comparison of the number of tags (from spring taggings) obtained from the various sub-district fisheries in the last two seasons of fishing is given below:—

Sub-district Fishery	Number of Detector Recoveries 1951–52	1953–54
Queen Charlotte Islands	----	---
Northern	50	3
Central	42	13
Upper east coast	1	4
Middle east coast	34	8
Lower east coast	83	28
West coast	16	11
Totals	226	67

The marked reduction in the number of detector recoveries results from the continuous operation of only one detector, and from the reduced efficiency of this detector compared to previous years. The greatest reduction in detector efficiency occurred during the early part of the season and, hence, the effect is most noticeable in the returns from the middle east coast and lower east coast sub-districts, where early fisheries occurred.

The number of tags recovered by detectors* in 1953–54 is considered too small for the reliable calculation of the "probable" number of tags in the catches in the various sub-districts and of certain population statistics. An analysis of the movement between populations has been based on the "probable" number of tags in the catches derived from plant magnet recoveries. The methods used and results obtained will be discussed in the next section. Information on the area of recovery of magnet returns is not, however, sufficiently precise or reliable to permit an analysis of movement within populations.

Recovery of Tags by Plant Crews

In 1953–54, 4,548 tags were recovered from magnets and plant machinery in fourteen reduction plants. This total represents a slight increase over the previous record total of 4,512 recoveries, obtained in 1951–52. A large number of recoveries was expected because of the heavy taggings in 1952 (60,887) and 1953 (81,390), and the very reduced fishery of 1952–53. The number of 1953–54 recoveries made at each plant is given in the following table:—

Plant	Number of Tags Recovered	Plant	Number of Tags Recovered
Imperial	513	Port Edward	930
Colonial	302	Seal Cove	160
Gulf of Georgia	102	Kildonan	130
Phoenix	308	Port Albion	377
North Shore	318	Nootka	175
Namu	259	Ceepeecee	239
Butedale	732	Hecate	3

The distribution of tags by area of tagging and probable sub-district of recovery is shown in Table II. Three of the tags recovered were from a tagging made in the Hood Canal, Washington, by American investigators in April, 1953. One was recovered during the summer fishery off Swiftsure Bank (Area 21), another in the early fall fishery off William Head (Area 19), and the third from the regular winter fishery, probably from Area 23.

* Detector recoveries shown by area of tagging and area of recovery are given in Supplementary Table II, and will be supplied upon request.

While the area of recovery of detector returns is always specific, it is often difficult to determine accurately the area and sometimes even the sub-district from which a plant magnet recovery originated. Because of the uncertainty attached to the areas of recovery, plant magnet returns are generally of more limited value in studying the movements of herring than detector recoveries. However, the fact that the number of plant magnet returns is much greater than the number of detector recoveries is often a distinct advantage in examining the general movements of herring. This is particularly true this season, when the number of detector recoveries is too small to permit reliable inferences to be drawn from them. The same methods as employed in previous years (Tester and Stevenson, 1948) are used to assign the most probable area of recovery to each plant magnet return. Table II shows that for 487 tags, or 10.7 per cent, the most probable area of recovery could not be readily determined. However, an examination of the returns certain as to area of recovery showed that the arbitrary assignment of the "doubtful" recoveries to the area of tagging would lead to correct assignment of area of recovery at least in 80 per cent of the cases. The "probable" number of tags in the catches of the various sub-districts shown in Table III were calculated from the actual number of plant magnet returns, including those recoveries arbitrarily assigned to their area of tagging, by applying corrections for magnet efficiency and for the fact that not all the catch was searched by magnets. The recoveries by plants where no magnet-efficiency tests were carried out were omitted in making the calculations. Table III is summarized in the tabulation below, which shows the "probable" number of tags in the catches by sub-district of taggings and probable sub-district of recovery. All actual numbers on which the calculations are based are given in parentheses:—

Sub-district of Tagging	Sub-district of Recovery							Total
	Queen Charlotte Islands	Northern	Central	Upper East Coast	Middle East Coast	Lower East Coast	West Coast	
Queen Charlotte Islands	17 (12)	3 (2)	4 (4)	.....	.....	.....	1 (1)	25 (19)
Northern	3 (2)	927 (798)	21 (19)	3 (3)	1 (1)	.....	.....	955 (823)
Central		83 (71)	1,503 (1,394)	6 (6)	8 (7)		1 (1)	1,601 (1,479)
Upper east coast	.....	.....	.....	103 (97)	.....	.....	.....	103 (97)
Middle east coast	.....	.....	.....	.....	216 (202)	46 (40)	12 (11)	274 (253)
Lower east coast	.....	.....	.....	1 (1)	36 (33)	161 (135)	32 (29)	230 (198)
West coast	.....	3 (2)	1 (1)	2 (2)	3 (3)	57 (49)	1,892 (1,200)	1,958 (1,257)
Totals	20 (14)	1,016 (873)	1,529 (1,418)	115 (109)	264 (246)	264 (224)	1,938 (1,242)	5,146 (4,126)[1]

[1] The difference between this total and the total number of magnet recoveries shown in Table II arises from the omission of returns from plants where no magnet tests were carried out.

The marked tendency for tags to be recovered in the sub-district of tagging noted in previous years in the analysis of both detector and magnet returns, is again shown. The relative strength of the "homing tendency" in the various populations cannot readily be compared because of unknown differences in the exploitation of the populations in the various sub-districts. However, this tendency would appear to be most pronounced in the northern, central, upper east coast, and west coast sub-districts, and least in the middle east coast, lower east coast, and Queen Charlotte Islands sub-districts.

Movement of herring from the west coast of Vancouver Island to other sub-districts was calculated to be about 3 per cent (66/1,958) and in 1953–54, considerably lower than the corresponding emigrations, based on detector returns, noted in 1951–52 (8 per cent), in 1950–51 (15 per cent), and in 1949–50 (12 per cent). While movement was shown to all other sub-districts except the Queen Charlotte Islands, the bulk of the movement was to the lower east coast. From all west coast areas, movement was to the lower east coast. From all west coast areas, movement to the lower east coast amounted to 2.9 per cent (57/1,958), approximately the same as in 1950-51 and somewhat greater than the 1.2 per cent (from the detector returns) noted in 1951–52. This emigration to the lower east coast was greater from Area 23 (5 per cent) than from other west coast

areas (1 to 2 per cent). The movement of lower east coast herring to the west coast amounted to 13.5 per cent (32/230), approximately the same as in 1950–51 (10.5 per cent, detector returns) and greater than the 7.5 per cent (magnet returns) noted in 1951–52. The disparity in the movements in the two directions between the west coast and lower east coast sub-districts may result partially from differences in exploitation rates in the two populations.

Magnet recoveries in 1953–54 again showed the relatively great dispersal of middle east coast and lower east coast tags to other sub-districts. Approximately 17 per cent (46/274) and 5 per cent (12/274) of the middle east coast tags recovered were from the lower east coast and west coast respectively, and 16 per cent (36/230) and 13.5 per cent (32/230) of the lower east coast tags were from the middle east coast and west coast respectively. The movements indicated between the middle east coast and the lower east coast are of approximately the same magnitude as in previous years. The movement to the lower east coast of fish tagged in Area 14 (22 per cent), was greater than that for fish tagged in Area 15 (12 per cent). Similarly, the movement to the middle east coast of fish tagged in Area 17A (38 per cent) was greater than those for fish tagged in Area 17B (10 per cent) or Area 18 (2 per cent). On the other hand, the movement of lower east coast fish to the west coast was greater for those tagged in Area 17B and 18 (14 per cent and 16 per cent, respectively) than for those tagged in Area 17A (10 per cent).

The main movement of fish from the northern sub-district (2 per cent, 21/955) was to the central sub-district. This is somewhat less than the 5.9 per cent found from detector returns in 1951–52. The main movement of central fish (5 per cent, 83/1,601) was to the northern sub-district, and corresponds closely to that shown by detector recoveries in 1951–52. It is interesting to note that the movement of fish tagged in Area 5 to the central sub-district (9 per cent) was greater than the movement of fish tagged in Area 4 (2 per cent); conversely, the movement of fish tagged in Area 6 to the northern sub-district (20 per cent) was greater than the movement of fish tagged in Area 7 (1 per cent). Also, the movement of fish tagged in Area 10 to the upper east coast sub-district (8 per cent) was greater than the movement of fish tagged in Areas 6 or 7 (less than 1 per cent). However, it should be pointed out that the movements of fish tagged in Areas 5 and 10 are based on a much smaller number of recoveries than those for Areas 4, 6, or 7.

Because of the small number of recoveries from Queen Charlotte Island taggings (Area 2B-E), only guarded statements can be made of the movements of fish. There was apparently approximately equal emigration (12 per cent and 16 per cent respectively) to the northern and central sub-districts, with a small movement (4 per cent), based on one tag return, to the west coast of Vancouver Island. It is interesting to note that while there was a heavy fishery in Area 2A-E, no Area 2B-E tags were recovered there. This would suggest that perhaps the herring stocks in these two areas are separate. Further data, however, would be required to confirm this.

Tagging during the 1954 Spawning Season

The 1954 tagging programme was carried out by two seine-boats loaned by fishing companies. One vessel began tagging operations on February 22nd in the lower east coast sub-district, and moved to the west coast sub-district later in the week. After tagging the west coast, this vessel moved through the central sub-district to the northern sub-district and later to Area 2B-E in the Queen Charlotte Islands, completing her tagging operations about April 3rd. The second vessel commenced operations on February 25th in the lower east coast and middle east coast sub-districts, moving later to the central sub-district, where she completed her tagging operations on April 1st. Herring were tagged in Area 2A-E for the first time this year. These herring spawn late in the season; in the week following May 10th, three taggings were carried out in Skidegate

Inlet by the herring investigation in co-operation with officers of the Department of Fisheries.

The numbers of herring tagged in the various areas in 1953 and 1954 are shown in the following tabulation:—

Year	Sub-district and Area of Tagging																	Total
	Queen Charlotte Islands		Northern		Central		Upper East Coast	Middle East Coast		Lower East Coast			West Coast					
	2A-E	2B-E	4	5	6	7	12	14	15	17A	17B	18	23	24	25	26	27	
1953		4,111	6,244		2,084	13,526	1,342	3,982	2,026	4,051	7,178	1,987	15,688	4,764	7,767	4,612	2,028	81,390
1954	4,070	2,996	6,064	2,025	2,006	4,075		1,503	1,511	2,015	2,006	4,053		2,072	4,069	.....	.....	38,465

Because of a delay of a week for repairs to the tagging-boat, the whole west coast tagging programme was adversely affected; the major spawnings in Areas 23, 26, and 27 were missed and, as a result, no fish could be found for tagging. Similarly, repairs to the other tagging-vessel resulted in a reduction in the tagging programme for the central sub-district.

SAMPLING OF THE CATCHES AND THE SPAWNING RUNS

Fundamental information on age composition, growth rate, sex ratio, and sexual maturity in the various populations is obtained from random samples taken from the fishing and the spawning runs. Samples were taken in the same manner as in previous years (Tester and Stevenson, 1947). The determination of the ages of the fish in these samples provides the basic data for the assessment of the relative strength of the various year-classes in the populations. Variations in the growth rate of the herring may reflect changes in feeding conditions. These variations will be disclosed by a comparison of length and weight measurements from year to year. Data on the sex ratios and degree of maturity link together certain phases of the adult spawn studies.

During the winter fishery a total of 80 samples were taken in the lower east coast sub-district and 71 samples in the west coast sub-district. The distribution of these samples* by areas is shown in the tabulation below (with comparable data for 1951–52 in parentheses):—

	Number of Samples	
	Winter Runs	Spawning Runs
Lower east coast—		
Area 17A	14 (72)	1 (3)
Area 17B	28 (20)	1 (5)
Area 18	38 (8)	2 (1)
Totals	80 (100)	4 (9)
West coast—		
Area 23	51 (25)	0 (14)
Area 24	12 (3)	1 (4)
Area 25A	1 (3)	1 (4)
Area 25B	3 (9)	1 (4)
Area 26	1 (3)	0 (4)
Area 27	3 (0)	0 (2)
Totals	71 (43)	3 (32)
Grand totals	151 (143)	7 (41)

* Lists of all winter and spawning samples taken on the west coast and the lower east coast of Vancouver Island in 1953–54, including places and dates of sampling, numbers of fish of each age and of each sex, and data on maturity, will be supplied on request (Supplementary Tables III and IV respectively).

Age Composition

West Coast Population

The average percentage age composition for the west coast population as derived from samples taken during the fishery is given below for the last eight seasons. The data for all seasons, except 1952–53, are weighted according to the numbers of fish caught in each statistical area. Because there was no fishery in 1952–53, the data for that season are weighted according to the number of samples taken in each area.

Season	In Year of Age								
	I	II	III	IV	V	VI	VII	VIII	IX and Over
1946–47	+	5.0	53.0	32.1	6.0	2.5	0.9	0.5	0.1
1947–48	+	2.4	58.2	27.8	8.5	2.1	0.5	0.3	0.1
1948–49	+	7.4	45.2	32.9	9.6	3.4	1.0	0.3	0.1
1949–50	+	4.4	68.8	20.5	5.3	0.8	0.2	0.1	.....
1950–51	+	9.8	35.3	44.5	8.0	1.9	0.5	+	+
1951–52	+	2.6	36.2	23.9	31.6	4.3	1.2	0.2	+
1952–53	0.1	7.3	61.7	28.5	1.8	0.5	0.1	.....	.....
1953–54	0.1	2.0	59.5	30.4	6.5	1.0	0.4	0.1	+

Note.—Plus signs indicate percentages of less than 0.05.

In 1952–53, in spite of the lack of information on absolute abundance in the fishable stock (in terms of numbers of fish), it was considered that the 1950 year-class was of above-average strength on the basis of its contribution as III-year fish (Stevenson and Outram, 1953). The proportion of this year-class (IV-year fish) formed of the catches in 1953–54 and its contribution in terms of numbers of fish suggest that it may be of no more than average strength. The contributions* of the various year-classes in millions of fish are tabulated below:—

Season	In Year of Age									Total
	I	II	III	IV	V	VI	VII	VIII	IX and Over	
1946–47	0.13	27.02	288.72	174.70	32.53	13.65	4.88	2.49	0.47	544.79
1947–48	0.13	10.03	240.18	114.60	35.16	8.76	2.24	1.10	0.56	412.76
1948–49	0.30	36.83	224.02	163.00	47.52	16.84	5.05	1.66	0.45	495.67
1949–50	0.13	14.89	233.67	69.68	17.86	2.69	0.65	0.20	0.00	399.77
1950–51	0.08	22.27	80.17	100.93	18.05	4.36	1.04	0.04	0.04	226.98
1951–52	0.06	6.08	86.39	56.99	75.55	10.20	2.89	0.53	0.06	238.76
1952–53	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
1953–54	0.27	7.89	230.26	117.75	25.05	3.99	1.54	0.18	0.09	387.02

The 1951 year-class (III-year fish) entered the fishery strongly in 1953–54. The proportion of III-year fish in the runs was comparable to that of 1952–53, and exceeds that of all other recent years with the exception of 1949–50, when the unusually abundant 1947 year-class entered the fishery in force. In terms of numbers of fish, the contribution of the 1951 year-class was about three times that either of the 1948 or 1949 year-classes as III-year fish, and compared favourably with that of the 1947 year-class. It is, therefore, considered that the 1951 year-class, while probably not as strong as the very abundant 1947 year-class, is of above-average strength.

In the winter runs of herring, there was a difference in age composition between the south west coast areas (Areas 23, 24, and 25A) and the north west coast areas (Areas 25B, 26, and 27); the 1951 year-class composed a greater proportion of the runs in the south than in the north, and the 1950 year-class was proportionately better represented in the north than in the south (Table IV). The relatively greater strength of the 1951

* The numbers of fish (in millions) of each age in the 1953–54 catches in each west coast area are given in Supplementary Table V, and will be supplied upon request.

year-class in the south and of the 1950 year-class in the north was indicated in the 1952–53 sampling data (Stevenson and Outram, 1953). In 1952–53, the 1949 year-class was more prominent in the south than in the north. However, in 1953–54, as V-year fish, this year-class was relatively abundant in the north. The tendency for older fish to be better represented in the runs of the more northerly west coast areas has been noted in previous years (Stevenson, Hourston, Jackson, and Outram, 1952).

The representation of II-year fish (1952 year-class) was the lowest in recent years in the south west coast areas; none were found in the sample from the north west coast areas. The proportion of II-year fish in the west coast catches has been found to be a generally reliable indication of future year-class strength (Stevenson and Outram, 1953). Considering the relatively great dependence of the fishery in the more southern areas on III-year fish, it is unlikely that the catches in these areas in 1954–55 will be as good as those in 1953–54. The catches in the more northern areas depend more on III- and IV-year fish; from the relative weakness of the 1951 and 1952 (III-year fish and II-year fish respectively) year-classes in these areas in 1953–54, it would appear unlikely that better catches will be made in these areas in 1954–55.

Lower East Coast Population

For the lower east coast runs, the average age composition and the contribution* of the various age-classes in millions of fish for the last six seasons are given in the tabulations below. In all years except 1952–53, the age composition has been weighted according to the numbers of fish caught in each area; in 1952–53, weighting was according to the number of samples taken in each area.

AVERAGE PERCENTAGE AGE COMPOSITION

Season	In Year of Age								
	I	II	III	IV	V	VI	VII	VIII	IX
1948–49	+	2.8	76.8	17.8	2.0	0.5	—	—	—
1949–50	+	1.5	66.7	26.9	4.1	0.6	0.1	+	—
1950–51	+	4.1	63.4	25.0	6.1	1.0	0.2	0.1	+
1951–52	+	6.6	57.5	27.1	7.0	1.3	0.3	0.1	+
1952–53	0.1	2.7	60.5	32.8	3.2	0.5	0.1	+	—
1953–54	—	0.8	58.0	34.2	6.2	0.6	0.1	+	+

NOTE.—Plus signs indicate percentages of less than 0.05.

NUMBERS IN MILLIONS OF FISH

Season	In Year of Age									Total
	I	II	III	IV	V	VI	VII	VIII	IX	
1948–49	0.26	11.21	312.63	71.43	7.94	1.75	—	—	—	412.22
1949–50	0.10	5.41	246.24	101.51	16.17	2.54	0.58	0.10	—	372.65
1950–51	0.12	15.97	245.91	90.67	21.43	4.48	0.76	0.24	0.03	379.61
1951–52	0.23	29.52	201.13	83.93	23.54	4.30	1.24	0.29	0.06	344.24
1952–53	0.12	1.99	51.15	30.30	2.96	0.50	0.06	0.03		87.12
1953–54	—	3.54	258.18	165.75	29.75	3.03	0.67	0.20	0.09	488.21

The percentage age composition for the sub-district as a whole in 1953–54 was very similar to that of the preceding four years. No differences were found in the pattern of age distribution in either the winter or the spawning runs (Table V) to the three major areas in the sub-district. As has been pointed out in previous reports (Stevenson and

* The numbers of fish (in millions) of each age in the 1953–54 catches in each lower east coast area are given in Supplementary Table VI, and will be supplied upon request.

Outram, 1953 and Stevenson, Hourston, Jackson, and Outram, 1952), the lack of variation in age composition in the winter runs to the three areas is explained by the single migration route followed by the herring from the offshore summer feeding-grounds to the inshore fishing and spawning grounds. The runs destined for the more northerly areas pass through the more southerly areas, where the major fishery usually develops.

Evidence from catch data and extent of spawn (discussed in a later section of this report) suggest that population abundance was greater in 1953–54 than in the previous year. From this and the uniformity of age composition in recent years, it is presumed that the 1951 year-class (III-year fish) was of above-average abundance.

The contribution of II-year fish (1952 year-class) was the smallest in recent years. Although the relative abundance of II-year fish on the lower east coast is not as reliable an indication of year-class strength as on the west coast, it is possible that the 1952 year-class may not be as strong as its predecessors. However, because of the generally high level of abundance of this stock in recent years, it is likely that the quota will be taken readily next year, though possibly more effort may be required to do so.

Sex Ratio and Stage of Development

The sex ratio (number of females divided by the number of males) and the sexual development of the herring in samples taken from the fishery in 1953–54, and from the spawning runs in 1954, are shown by areas in Tables VI and VII for the west coast and lower east coast populations respectively. The sampling of spawning runs in both the west coast and lower east coast sub-districts is not considered adequate to permit detailed analysis of sex ratio and sexual development.

West Coast Population

The sex ratios obtained for the sub-district and for most of the individual areas are similar to those of recent years. Usually, males and females are about equally prevalent (with slight tendency for females to predominate) in the commercial catches, whereas males outnumber females in the spawning runs. The explanation of this situation lies in the tendency of females to live slightly longer than males, and of the average age in the spawning runs to be less than in the winter runs (Stevenson and Lanigan, 1950). In 1953–54, the unusually high sex ratio in Area 25A and the high sex ratio in Area 26 probably resulted from inadequate sampling of the runs, only one sample being obtained from each of these areas.

Because of the relatively poor representation of II-year fish, the percentage of immature fish in the winter runs was considerably smaller than in 1952–53, but was about average or slightly below average for recent years. No spent fish were found in the winter runs. No immature fish were found in the spawning runs in 1954; however, these runs are considered to have been inadequately sampled.

Lower East Coast Population

The sex ratio in the lower east coast winter samples has shown a tendency to decrease slightly in the last three years. In 1951–52 it was 0.88; in 1952–53, 0.84; and in 1953–54, 0.81. At present, evidence is insufficient to show whether this progressive decrease is real or whether it is simply due to sampling variation. The reason for the greater representation of males in the lower east coast population as compared to the west coast population has been attributed to the generally younger average age of the lower east coast herring (Stevenson and Outram, 1953). However, this explanation does not adequately account for differences in sex ratios in the two populations in 1953–54. The average age of the winter runs to the west coast sub-district, and particularly to the south west coast areas, was less than that in the winter runs to the lower east coast sub-district; yet the representation of males was greater in the latter than in the

former. However, as was noted above, on the west coast, the average age in the spawning runs is less than in the winter runs. On the other hand, on the lower east coast, the differences in average age and in the proportion of males and females between winter and spawning runs are less pronounced. This would suggest that on the west coast older and predominantly female fish move inshore before the younger and predominantly male fish, whereas on the lower east coast young and old fish move inshore at approximately the same time.

In spite of the average age of the lower east coast herring being slightly greater in 1953–54 than in 1952–53, the proportion of immature fish in the winter runs was somewhat greater. The percentage of immature fish was considerably greater in Area 17A than in either Area 17B or Area 18.

No spent fish were found in winter runs, and no immature fish in the spawning runs.

Average Length and Weight

Variations in the average length and weight of herring of any particular age from year to year probably reflect changes in environmental conditions (food-supply, temperature, etc.) influencing growth. The average weight of the various age-groups, together with the age composition, are used to calculate the numbers of fish in the commercial catches. The average lengths and weights of west coast herring in the 1953–54 winter runs are shown in Table VIII, and the average lengths of herring in the 1954 spawning runs in Table IX. Comparable data for the lower east coast herring are shown in Tables X and XI respectively.

No striking or consistent differences were found in the average lengths of each age-group of fish in the winter runs to the west coast areas. However, there was a small but consistent difference in average weights; fish of each age-group in Barkley Sound tended to be slightly heavier than those in other areas. Herring undergo a loss of weight in winter, when feeding does not normally take place. The differences in average weights between herring from Area 23 and those from other west coast areas are probably attributable to this cause. Approximately 90 per cent of the catch in Area 23 was made before Christmas, whereas the bulk of the catch in other west coast areas was made after Christmas.

No consistent differences in average length or average weight were noted among herring of the various age-groups from the three lower east coast areas.

The average lengths and weights of herring from the lower east coast and west coast populations are given below for the major age-groups in the winter runs for the last six years:—

Year	Lower East Coast Population					West Coast Population				
	II	III	IV	V	VI	II	III	IV	V	VI
Length in millimetres—										
1948–49	162	187	199	218	233	159	188	201	213	222
1949–50	153	188	200	211	211	164	190	202	212	220
1950–51	153	188	200	211	220	158	188	204	215	220
1951–52	151	185	198	209	217	159	187	205	217	226
1952–53	156	184	196	209	214	162	185	198	209	222
1953–54	152	187	200	211	223	161	185	200	211	223
Weight in grams—										
1948–49	54	85	104	131	154	50	87	111	138	158
1949–50	45	91	111	131	148	56	94	117	137	152
1950–51	42	91	113	137	150	50	88	114	135	149
1951–52	46	91	114	139	158	53	90	114	139	157
1952–53	45	77	94	119	135	51	80	100	119	149
1953–54	46	88	108	127	149	54	86	105	126	147

The striking reduction in average weight in all age-groups, except II-year fish, in both the west coast and lower east coast in 1952–53, was attributed to unusually poor

feeding conditions during the summer of 1952 (Stevenson and Outram, 1953). In 1953–54, the average weights of herring above age II in both populations showed a noticeable increase over the average weights of the previous year, but still remained somewhat below normal. The increase in average weights over those of 1952–53 would suggest that feeding conditions were probably more normal during the summer of 1953. Two explanations for the fact that average weights in 1953–54 were still slightly lower than in the period 1949–52 are suggested: (1) The effect of poor feeding conditions in 1952–53 might be felt in succeeding years if there was little or no compensatory growth; that is, if growth in 1953–54 was not greater than average; or (2) the lack of a large-scale fishery in 1952–53 may have resulted in the presence on the grounds at some period of the year of a larger than normal supply of fish, thus causing increased competition for food.

The fact that II-year fish maintained their normal weight during the last two seasons while older fish fluctuated in weight suggests that they were not exposed to the same changes in feeding conditions. The inference was made that the period of unfavourable feeding conditions occurred before the time of recruitment of II-year fish to the fishing stock (Stevenson and Outram, 1953).

There were no appreciable differences in the average lengths of fish in 1953–54 as compared to previous years in either the lower east coast or west coast populations.

Spawning samples in both populations were not sufficiently numerous to allow reliable comparison of average lengths to be made.

EXTENT AND INTENSITY OF SPAWNING

The extent and intensity of herring-spawn deposition on the west coast and lower east coast of Vancouver Island was estimated again in the spring of 1954.* Since 1947, two independent surveys have been carried out on the west coast, one by members of the herring investigation, the other by fisheries officers. On the lower east coast, a single survey by fisheries officers is made. The main purpose of the spawn surveys is to provide information on the relative size of the spawning stock—that is, the relative size of the escapement from the winter fishery—and on the relationship between the amount of spawn deposited and the size of the resulting year-class. Methods employed in the surveys were similar to those of previous years (Tester and Stevenson, 1948).

West Coast Population

West coast spawnings in 1954 followed the general pattern of spawning in previous years, except that spawnings in the latter part of March were less frequent than usual. The mains spawning-grounds were:—

Area 23: Macoah Passage, Toquart Bay, and Bamfield Inlet.
Area 24: Cypress Bay and Flores Island (east shore).
Area 25: Nuchatlitz Village vicinity and the south shore of Esparanza Inlet.
Area 26: Malksope Inlet and Bunsby Islands.
Area 27: Winter Harbour.

The earliest spawning occurred at Port Langford (Area 25) on February 6th, and the latest on April 20th at Saltery Bay (Area 25). Other early spawnings in February took place at Toquart Bay and Roquefeuil Bay in Area 23, at Cypress Bay and Big Whitepine Cove in Area 24, at Nuchatlitz Village and Port Langford in Area 25, and at Klaskish Inlet in Area 27. Late spawnings in April occurred at Useless Inlet and Toquart Bay in Area 23, at Newton Cove and Saltery Bay in Area 25, at Malksope Inlet in Area 26, and at Apple Bay in Area 27.

* A list of the individual spawning localities in the west coast and lower east coast sub-districts, with dates, intensities, and extent of spawn depositions, will be supplied on request (Supplementary Tables VII and VIII).

The most noticeable features of the 1954 spawnings were:—

(1) The persistence for the second year of the increased deposition in Bamfield Inlet (Area 23).
(2) The decrease in the number of spawnings in Macoah Passage (Area 23).
(3) A spawning in Hootla Kootla on the east shore of Flores Island (Area 24) for the first time since 1950.
(4) A large spawning in the vicinity of Nutchatlitz Village (Area 25) for the fifth consecutive year. This spawning accounted for nearly 70 per cent of the spawn deposition in Area 25.
(5) A spawning in Nasparti Inlet (Area 26) for the first time since 1951.
(6) The absence of a spawning in Ououkinsh Inlet (Area 26) for the fourth consecutive year.

A summary of the extent of spawn deposition on the west coast since 1947 is given by statistical areas in the following table, with intensity of spawn deposition in parentheses. The extent of spawn deposition is recorded in statutory miles and the average intensity is calculated by weighting the intensities of individual spawnings—very light, light, medium, heavy, and very heavy—in the ratio of 1, 2, 3, 4, and 5 respectively.

Year	West Coast Areas					Total Miles, All Areas
	23	24	25	26	27	
1947	13.2 (3.3)	6.0 (3.6)	9.3 (3.8)	2.5 (2.9)	1.4 (2.7)	32.4 (3.4)
1948	10.9 (3.0)	8.4 (3.3)	12.8 (3.0)	2.0 (2.8)	9.7 (2.2)	43.8 (2.9)
1949	11.7 (3.1)	4.3 (3.1)	16.3 (3.5)	2.2 (3.4)	6.6 (2.6)	41.1 (3.2)
1950	13.4 (2.4)	4.2 (2.8)	18.2 (3.2)	3.2 (3.3)	4.5 (3.0)	43.5 (2.9)
1951	8.8 (2.9)	11.4 (1.3)	28.3 (3.4)	1.5 (3.4)	4.9 (3.1)	54.9 (2.8)
1952	6.2 (2.6)	5.6 (2.3)	21.4 (3.7)	1.4 (2.8)	1.1 (3.2)	35.7 (3.3)
1953	14.5 (2.1)	8.4 (2.6)	27.4 (3.8)	4.4 (3.0)	9.6 (3.6)	64.3 (3.2)
1954	9.0 (2.2)	7.4 (2.8)	19.6 (3.0)	3.8 (2.8)	6.5 (3.3)	46.3 (3.2)

Figure 2A shows the amount of spawn deposited in each area, and in the west coast sub-district as a whole, for the last eight years.

The extent of spawn deposition on the west coast in 1954 showed a decrease of approximately 28 per cent from the record spawning of 1953, but remained the third largest recorded since 1947. The decrease was reflected in all areas, but was greatest in Area 23 (38 per cent), Area 27 (32 per cent), and Area 25 (28 per cent), and least in Areas 24 (12 per cent) and 26 (13 per cent). The decrease in Area 23 resulted at least in part from the reduced number of spawnings in Macoah Passage, and in Areas 25 and 27 from a general decrease in the number of spawnings. In Areas 24 and 26 the reappearance of spawnings on the east side of Flores Island (Area 24) and Nasparti Inlet (Area 26) prevented declines in these areas proportional to those in other areas.

The average spawning intensity in 1954 for the west coast as a whole was the same as in the previous season. Spawning intensity showed a decrease in Areas 25, 26, and 27, and a slight increase in Areas 23 and 24. However, these increases were not sufficient to compensate for the decreases in spawning extent.

A decrease in spawn deposition from the high level of the previous year was to be expected in 1954, unless there had been phenomenally heavy recruitment; the heavy deposition in 1953 was the result of the lack of a fishery in 1952–53. Proportionately the greatest decrease occurred in Area 23, which contributed the major portion of the catch. However, there is no evidence that the 1954 spawn deposition on the west coast as a whole, or in Area 23 in particular, is below that necessary to maintain the population. The 1947 year-class was extremely abundant in all west coast areas, and resulted from a considerably smaller total spawning. The 1951 year-class is considered to be above average in the south west coast areas, yet in 1951 spawn deposition in Area 23 was slightly less than in 1954.

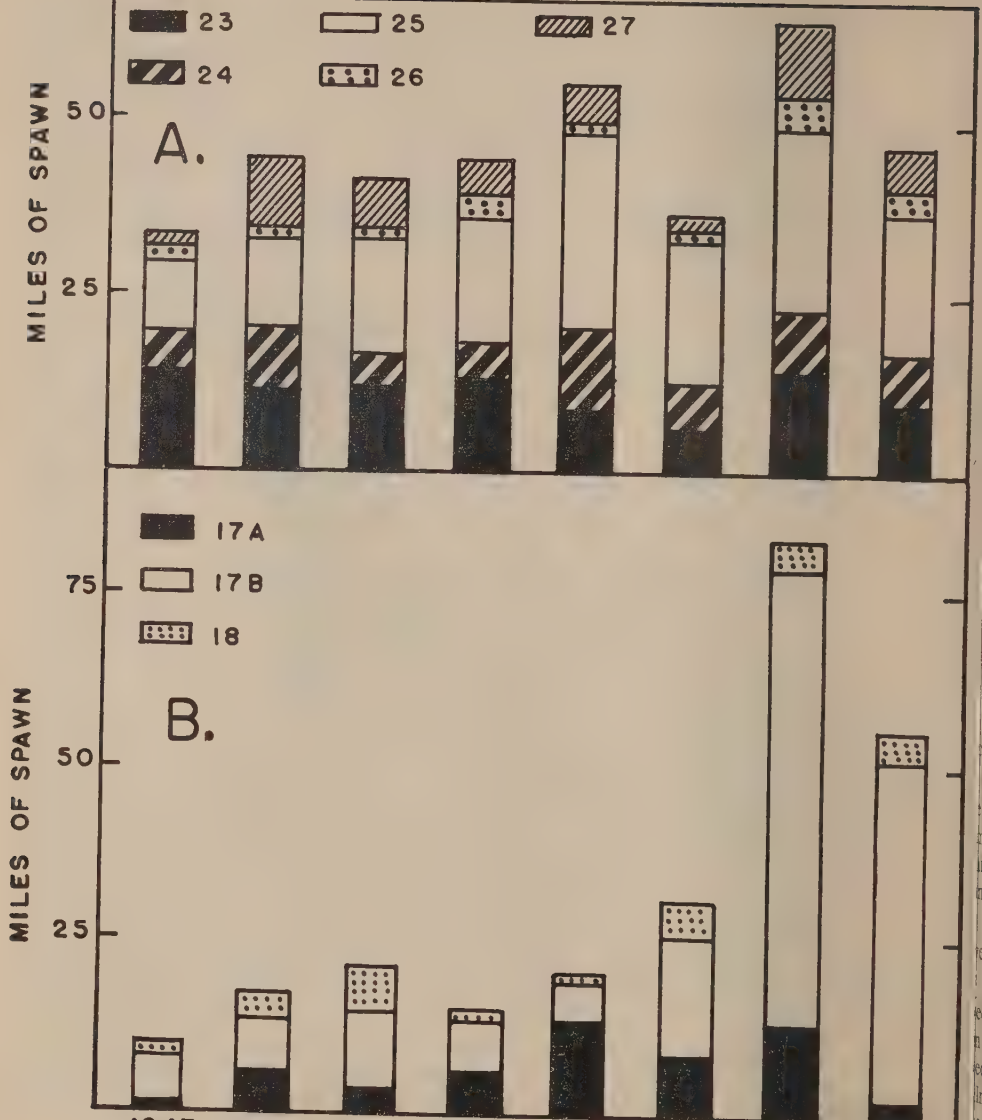

Fig. 2. Miles of herring-spawn deposited in statistical areas of the west coast of Vancouver Island sub-district, A, and the lower east coast of Vancouver Island sub-district, B.

In Area 25, spawn deposition has decreased progressively since 1951, with the exception of 1953, when, however, the increase in this area was proportionately less than in other west coast areas. In contrast to above-average catches made in other west coast areas, the 1953–54 catch in Area 25 was one of the lowest since unrestricted fishing was permitted. The decrease in spawn deposition and in catch indicated that population abundance in Area 25 has declined from the exceptionally high level of 1950–51 and 1951–52. It is unlikely that unrestricted fishing has occasioned the decline, but rather that natural fluctuations in recruitment are the cause. The 1951 year-class, as III-year fish, was relatively poorly represented in Area 25, in spite of the record spawn deposition in this area in 1951.

Lower East Coast Population

A summary of the extent of spawn deposition on the lower east coast since 1947 is given by areas in the following tabulation. Intensity of spawn deposition, shown in parentheses, is calculated in the same manner as for the west coast:—

Year	Lower East Coast Areas				Total Miles, All Areas
	17A	17B	18	19	
1947	1.5 (1.5)	6.1 (4.3)	2.2 (2.2)	0.1 (2.0)	9.9 (3.4)
1948	5.7 (1.8)	7.9 (3.2)	3.7 (2.5)	0.1 (1.0)	17.4 (2.6)
1949	3.6 (3.7)	10.8 (3.9)	6.4 (3.0)	0.1 (1.0)	20.9 (3.5)
1950	6.6 (4.4)	7.0 (3.4)	1.3 (1.7)	0.2 (1.0)	15.1 (3.7)
1951	12.7(2.9)	6.7 (2.6)	0.6 (1.3)	0.2 (1.0)	20.2 (2.7)
1952	8.7 (2.7)	18.0 (3.4)	4.6 (1.3)	0.2 (1.0)	31.5 (2.9)
1953	15.5 (3.4)	63.4 (3.9)	3.8 (2.0)	+ (+)	82.7 (3.7)
1954	2.0 (1.6)	49.9 (3.6)	3.9 (1.5)	+ (+)	55.8 (3.5)

Note.—Plus signs indicate negligible amounts of spawn.

Figure 2B shows the amount of spawn deposited in each area, and in the lower east coast sub-district as a whole, for the past eight years.

In 1954, the extent of spawn deposited on the lower east coast was the second highest ever recorded. The 55.8 miles of spawn represent a decrease of approximately the same magnitude as that on the west coast. Decreased spawnings occurred in both Areas 17A and 17B, which habitually account for the major proportion of the lower east coast spawning. The small increase in spawning in Area 18 is too slight to be of significance.

The average spawning intensity in 1954 decreased slightly from that of the previous year. The decrease was reflected in all areas, but was particularly great in Area 17A.

The most striking feature of the 1954 lower east coast spawnings was the tremendous reduction both in extent (87 per cent) and in intensity (53 per cent) of spawn deposition in Area 17A, principally in the Nanoose Bay region. Spawnings in Area 17B, although reduced by about 20 per cent from 1953, were still exceedingly heavy and accounted for almost 90 per cent of the sub-district spawnings. Successive waves of heavy spawning again occurred in this area along the shore-line between Ladysmith and Yellow Point.

As on the west coast, some decrease in spawn deposition was to be expected as a result of the resumption of fishing activities in the 1953–54 season. In spite of the tremendous decline in spawning in Area 17A, the extent of spawn deposition in 1954 is probably still far higher than is required to maintain population abundance at a high level.

DISCUSSION

In the foregoing sections of this report there have been presented analyses of the 1953–54 data on catch statistics, age composition, and spawn deposition in the populations in the west coast and lower east coast of Vancouver Island sub-districts, together with an analysis of the movement of herring between all major herring populations. In

this section, the bearing of these results on comparative study of the two stocks unde different methods of management is discussed, and the results obtained from this stud reviewed.

The size of the west coast catch, the third highest since 1948–49, coupled with th spawn deposition of above-average extent, indicates that population abundance in th west coast sub-district in 1953–54 has increased from the low level reached in 1951–52 Area 23 provided the major portion of the catch, with considerably above-average con tributions from Areas 24, 26, and 27. The catch in Area 25 was below normal, and wa less than that in Area 24 for the first time in eight years.

The catch in Area 23 in 1953–54, while considerably larger than the catches o 1950–51 and 1951–52, was slightly below the average for the period 1946–47 to 1949 50. Spawn deposition in Area 23 in 1954 was also greater than the deposition in 195 or 1952, but less than the annual deposition in the years 1947 to 1950. This suggest that while population abundance increased from the low level of 1950–51 and 1951–52 it has not attained the average level of abundance of the period 1947 to 1950.

In contrast to the evidence pointing to an increase in abundance in Area 23, ther are indications of a decrease in abundance in Area 25, the other major west coast fishin area. The 1954 catch in Area 25 was one of the smallest made during the period of th comparative study. The extent of spawn deposition in Area 25 has progressively de creased since 1951, with the exception of 1953, when the increase in Area 25 wa proportionately less than in other west coast areas.

The relative contributions of the various year-classes in the fishery provide a explanation of the changes in abundance noted in the two major west coast areas. I the south west coast areas, the decline in abundance in 1950–51 and 1951–52 was th result of the recruitment of two successive year-classes of below-average strength (th 1948 and 1949 year-classes). The increase in abundance in this region in 1952–53 an 1953–54 has resulted from the recruitment of two average or above-average year-classe the 1950 and 1951 year-classes. In the north west coast areas, the 1948 and 1949 yea classes were also weak, but because of the relatively great contribution made by the ver strong 1947 year-class as 4- and 5-year-old fish in 1950–51 and 1951–52, the decline i abundance was not as pronounced as in the south west coast areas. However, the 195 and particularly the 1951 year-classes do not appear to have been as strong in the nort west coast as in the south west coast areas, and with no strong contribution by older yea classes, abundance has declined.

On the lower east coast, abundance has continued at the high level that has existe since 1951-52. Following the record catch of 52,600 tons, spawn deposition in 195 although showing an expected decrease from the exceedingly high level of the previou year, was the second highest recorded. On the lower east coast, the 1949 year-cla was considerably stronger than on the west coast, and the 1950 and 1951 year-class have also been of above-average strength. Abundance was maintained in 1953–54 b the good recruitment of the 1951 year-class as III-year fish, and the above-average co tribution of the 1950 year-class as IV-year fish.

During the eight years the comparative study of the west coast and lower east coa population has been carried on, population abundance on the west coast has fluctuate

In the following tabulation, population estimates (in number of fish $\times 10^8$) for t west coast and lower east coast sub-districts for the past eight years are given. The estimates are based on data on catch and spawn deposition (Stevenson and Outra 1953). Exploitation rates, calculated as the ratio of catch to total population, a shown in parentheses:—

Sub-district	Season							
	1946–47	1947–48	1948–49	1949–50	1950–51	1951–52	1952–53	1953–54
st coast	8.97 (0.60)	8.26 (0.49)	9.50 (0.51)	7.84 (0.43)	7.90 (0.29)	6.51 (0.36)	7.26 (+)[1]	9.14 (0.44)
ver east coast	4.84 (0.72)	5.25 (0.66)	7.00 (0.58)	5.96 (0.63)	5.97 (0.63)	7.40 (0.51)	11.06 (0.08)	11.40 (0.43)

[1] Plus sign indicates negligible exploitation rate.

From 1946–47 to 1950–51 abundance remained at a generally high level, in 51–52 there was evidence that abundance had declined, and in 1952–53 and 1953–54 at abundance had increased again. These fluctuations in abundance have been ributed to variations in year-class strength due to changes in environmental conditions, obably during the critical larval and post larval stages, rather than to any effect of hing. There has been no evidence that spawn deposition in any year has approached critical minimum required to maintain abundance. In 1947 the poorest spawning curred, yet the resulting year-class was one of the largest on record. In 1951, spawning Area 23 was the poorest recorded to that time, while in Area 25 it was the highest corded. However, on the basis of its contribution as III-year fish in 1954, the 1951 ar-class appears to be stronger in Area 23 than in Area 25. The results of the study, refore, have indicated that the lack of quota restrictions has not adversely affected pulation abundance on the west coast, at least during a period of high population undance. It has appeared that in certain areas, particularly Area 25, natural limitaons on catch imposed by late inshore migration have been effective in maintaining high wn deposition. The lack of a fishery in 1952–53 prevented, at least for the present, assessment of the effects of unrestricted fishing during a period of low population undance.

On the lower east coast, population abundance has also fluctuated during the period the study, although not to the same extent or in the same manner as the west coast pulation. Population abundance increased from 1946–47 to 1948–49, decreased 1949–50 and 1950-51, and has apparently increased steadily since 1951–52. As on west coast, variations in year-class strength offer a logical explanation for the fluctuans in abundance. Spawning escapements, particularly in the last three years, appear have been much larger than necessary to maintain abundance. The year-classes of 49 and 1951 have all been of average or above-average size, yet these year-classes ulted from spawn depositions of at least one-third to one-half the size of the spawn positions of the last three years.

While the fluctuations in population abundance and the recent increases in spawn position may indicate that the present fixed quota has not been effective in stabilizing population and may have resulted in some wastage of fish during a period of high pulation abundance, other results have indicated that some form of control may be cessary to maintain this population. Furthermore, an analysis of tag-returns (Stevenn, 1954) has shown that the lower east coast stocks follow a single migration route m the offshore feeding-grounds to the spawning-ground, passing progressively through into each major area, in any of which the major fishery may develop. This single gration route thus may render these stocks particularly vulnerable. As the lower east st fishery develops early in the season, it seems probable that exploitation could readily increased, possibly even to an extent that would be detrimental to the stock.

The west coast and lower east coast populations were chosen for the comparative dy of two populations subjected to different methods of management because they were nsidered to be the most closely related stocks with regard to geographical location and tent of intermixture (Stevenson, Hourston, and Lanigan, 1951). The results of the st eight years of study have shown that certain fairly fundamental differences exist ween the two stocks.

1. An analysis of tag returns from 1936–1952 (Stevenson, 1954) has shown th the lower east coast stocks receive apparently quite substantial contributions from stock in the middle east coast sub-district, and that the stocks which spawn in the three majo lower east coast areas (Areas 17A, 17B, and 18) are completely mixed, and fail to sho significantly less intermixture with increase in distance separating the spawning-groun of the runs. The results of the west coast tagging indicate that there are two relative discrete sub-populations consisting of four main runs each. One sub-population con prises those runs to Areas 23 and 24; the other, those to Areas 25, 26, and 27. Inte mixture of the order of 25 per cent takes place between sub-populations and is greate between adjacent areas. An analysis of the relative contributions of the various yea classes in the west coast lends support to this conclusion. For instance, the 1947 yea class was more prominent in the north west coast fishery (Stevenson, Hourston, Jackso and Outram, 1952), while the 1951 year-class, as III-year fish, appears to be stronger the south west coast than in the north west coast fishery. There also appears to be a di ference in the pattern of recruitment. In the south west coast sub-population, recrui ment occurs at age III, whereas in the north west coast the recruitment occurs at age I and to an appreciable extent at age IV as well. In this respect this sub-populatio resembles the populations in Northern and Central British Columbia.

2. The inshore migration pattern of the lower east coast and west coast stock differs as has been mentioned; the lower east coast stocks follow a single migration rout whereas on the west coast the runs to the various areas probably approach the coa separately. The times of the inshore migrations to the lower east coast, south west coas and north west coast are progressively later. The main migrations to Areas 25 and 2 do not occur in some years until after the close of the fishery.

3. On the lower east coast, spawn survival is apparently higher and factors whic influence survival more constant than on the west coast. With the exception of the la two years, spawn deposition on the lower east coast has been less than on the west coas yet the average catch has been higher. The average west coast spawn deposition 43.1 miles for the 1947 to 1951 period was followed by an average catch of 33,500 to from 1949–50 to 1953–54, the seasons in which the catch was largely comprised of fi originating from the 1947 to 1951 spawnings. Comparable figures for the lower ea coast show that an average of 16.7 miles of spawn produced an average catch of 43,2(tons. The catches in 1952–53 were not considered in arriving at the average west coa and lower east coast catches.

4. No statistically significant relationship has been found between the fluctuatio in population abundance on the two sub-districts. From 1946–47 to 1950–51, pop lation abundance on the west coast exceeded that on the lower east coast by a fai constant amount. Since 1950–51, lower east coast abundance has been greater th west coast abundance, resulting primarily from the differential recruitment of the 19 and 1950 year-classes (Stevenson and Outram, 1953). There appears to have be a proportionately greater increase in population abundance on the west coast in 1953–5 which suggests that the 1951 year-class may have been stronger than on the lower ea coast.

While these differences would appear to throw some doubt on the usefulness of t lower east coast population as a control in the comparative study, it is unlikely that th will materially affect the validity of the main conclusions to be drawn from the experime or of their general applicability to other populations.

It is planned to investigate these apparent differences more closely and to determi to what extent stocks spawning in American waters contribute to Canadian catch particularly in the lower east coast sub-district. Increased emphasis will therefore placed on investigations of the lower east coast population. The tagging programme w be intensified in the Strait of Georgia region to elucidate the relationship between t middle east coast and lower east coast stocks. It is also intended to institute a low

ast coast spawn survey by herring investigators to obtain more information on spawn eposition and the factors affecting spawn survival. The intensification of research on ie lower east coast population will be made without diminishing the effort expended on ie west coast population.

SUMMARY

This is the eighth in a series of annual reports on the comparative study of two ajor herring populations, in one of which (the west coast of Vancouver Island popu-ition) unrestricted fishing is permitted, while in the other (the lower east coast of ancouver Island population) fishing is restricted by a fixed annual quota of 40,000 tons.

The west coast catch (41,350 tons) in 1953–54 was the largest since 1948–49. The ajor portion of the catch was made in Area 23, with above-average contributions from reas 24, 26, and 27. The catch in Area 25, the other major fishing area, was one of the nallest since unrestricted fishing has been permitted. Average catch per unit of effort r the west coast as a whole was the lowest recorded, slightly less than that for 1947–48, 949–50, or 1950–51. The extent of spawn deposition on the west coast was close to ie average for the period 1947 to 1954, and, coupled with the size of the catch, suggested iat abundance had increased from the low level of 1951–52 to approximately the level xisting prior to 1950–51. Population abundance increased in all areas with the excep-on of Area 25, where evidence points to a decrease in abundance.

The increase in population abundance resulted from good recruitment of the 1951 ear-class as III-year fish, together with the average or above-average contribution of ie 1950 year-class as IV-year fish. The decline in Area 25 is attributed to the relative eakness of the 1951 year-class in this area. The 1952 year-class, as II-year fish, were oorly represented in all areas, which suggests that this may not be a strong year-class.

On the lower east coast abundance continued at a high level for the fourth consecu-ve year. A record catch of 52,660 tons was taken (quota extensions totalling 15,000 ns were granted because of the expected large carry-over of the stock from 1952–53). lthough spawn deposition had decreased compared to 1953, it remained the second ghest ever recorded. The percentage decrease was similar to that on the west coast. he 1951 year-class was strongly recruited as III-year fish. The high level of abundance explained by the recruitment of four successive average or above-average year-classes.

The conclusions drawn from the past eight years of study of the west coast and lower ast coast populations were reviewed. It was pointed out that during periods of high opulation abundance, unrestricted fishing on the west coast had not affected population undance adversely, and the fixed quota on the lower east coast had not stabilized the undance there. The effects of unrestricted fishing in the one population and of a fixed uota on the other during periods of low population remained to be determined. lthough the fixed quota has not stabilized abundance on the lower east coast, the possi-lity exists that some form of restriction may be necessary to protect this population. was pointed out that the single migration route and early inshore migration render this opulation vulnerable, and that exploitation could readily be increased, possibly to a oint detrimental to the stock.

As a result of the study, certain fairly fundamental differences between the two opulations have come to light, but it is considered that these will not affect the main nclusions to be drawn or their general applicability to other stocks. Investigations are anned to obtain further information on these differences.

ACKNOWLEDGMENTS

The herring investigation is indebted to the fishing companies, herring-fishermen, id government fisheries departments for their indispensable support of herring research uring 1953–54.

Special acknowledgment and thanks are due to the fishing companies for generousl providing vessels on a charter-free basis, and space and facilities in various plants fo operation of tag-detectors and for sampling the catch. Francis Millard & Company pro vided the *Great Northern III* for use in the tagging programme; the Canadian Fishin Company Limited, the seiner *Bligh Island* and facilities for the operation of a tag-detecto in the Gulf of Georgia plant. The Anglo-British Columbia Packing Company mad available the *Fir Leaf* for the west coast spawn survey. British Columbia Packers Lim ited provided an additional power-skiff for the tagging programme, and space in the Imperial and Seal Cove plants for the operation of tag-detectors. Nelson Brothers Fish eries Limited allowed the installation of a tag-detector in their Colonial plant. Acknow edgment must be given to members of the staff of various plants for their contribution i collecting herring samples, and to captains and crews of the tagging and spawn-surve vessels for their valuable co-operation. The interest shown by the companies, their plan managers, foremen, and staffs in all phases of herring research was greatly appreciated

The captains of most of the herring-seiners again undertook to fill out and subm pilot-house records, providing us with valuable and otherwise unobtainable informatio relating to catch. It is with pleasure that we acknowledge their efforts and the continuin interest of all herring-fishermen in herring research.

The considerable assistance rendered by the Federal Department of Fisheri through the Chief Supervisor, A. J. Whitmore, and regional supervisors, G. S. Read and H. E. Palmer, is most gratefully acknowledged. For the tremendous effort require to carry out surveys on the extent and intensity of herring spawning in all coastal area special thanks are due to the fisheries officers who participated. In addition, thanks a due to the fisheries officers at Butedale and Bella Bella for carrying out magnet-efficienc tests in the plants in their areas. The efforts of the Chief Statistician and members his staff in making available final catch records of all fishing areas, and records of dai deliveries to the various plants during the progress of each fishery, are grateful acknowledged.

The interest of the Provincial Department of Fisheries and its Deputy Ministe G. J. Alexander, in continuing the publication of this series of reports, is deeply appr ciated. This report forms the eighteenth of the series.

The conscientious efforts and co-operative spirit of all members of the herri investigation have been sincerely appreciated. A. S. Hourston, assistant scientist, h carried on the investigation on juvenile herring and has provided valuable advice on phases of the research. D. N. Outram, assistant scientist, supervised the spawn studi and contributed in many ways to the efficiency of the investigation.

G. T. Taylor, administrative assistant of the herring investigation, compiled a analysed the catch data and contributed to the tagging and tag-recovery programm R. S. Isaacson, laboratory technician, assumed responsibilities for making age determ nations of all fish sampled from the winter and spawning runs. In addition, he supe vised the compilation of age and growth data, and contributed to their prelimina analysis. His assistance in assembling this report is also acknowledged.

All members of the staff assisted in the field work of the investigation. A spec tribute is due to A. G. Paul, senior field technician, who after twelve years with t herring investigation transferred to the less arduous position of maintenance supervis at this station. His unfailing co-operation and willingness, together with his great pra tical knowledge of all phases of field work and of the herring-fishery, have been of in timable value to the investigation and a tremendous example to all. During the 1953– season, Mr. Paul was again responsible for the supervision of the tagging and sampli programmes and for the maintenance of the nets and other equipment. Other membe of the herring staff, J. A. Bond, J. S. Rees, E. W. Stolzenberg, B. Wildman, and A. Rigl assisted in field programmes and in the preliminary analysis of data. W. Egeland, ca tain of the chartered vessel *Grassholm,* again provided valuable assistance and advice

ne juvenile herring field studies. Miss Diane Blackburn efficiently carried out stenographic and clerical duties.

Various members of the staff of the Pacific Biological Station rendered valuable assistance to the herring investigation. M. A. Pirart of the electronics laboratory carried on further work on the design and operation of tag-detectors. R. M. Wilson and W. G. St. Clair, port contact-men in Vancouver and Prince Rupert respectively, arranged for the collection of samples.

Thanks are due to Dr. A. L. Tester, visiting investigator from the University of Hawaii, and J. C. Stevenson, Assistant Director of the Pacific Biological Station, for constructive criticism of this report.

It is with sincere pleasure that acknowledgment is made of the valuable advice, encouragement, and direction supplied throughout the year by Dr. J. L. Hart, former director of this station and new director of the Atlantic Biological Station.

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* Reprints were published in year following the date of publication of report.

TABLES

Table I.—Catch (in Tons), Fishing Effort (Total Number of Active Fishing-days Ex pended by All Seine-boats), and Catch per Unit of Effort (Average Catch per Sein per Day's Active Fishing Effort) for West Coast and Lower East Coast Areas durin the 1953–54 Fishing Season.

Area	Catch	Fishing Effort[1]	Catch per Un of Effort
West Coast			
Area 23	24,200	482.9	50.2
Area 24	5,350	76.3	70.1
Area 25	5,000	222.5	22.5
Area 26	2,700	76.4	35.3
Area 27	2,100	36.6	57.4
Totals	39,350	895.0	44.0
Lower East Coast			
Area 17A	4,000	72.7	55.0
Area 17B	18,350	204.5	89.8
Area 18	30,000	348.5	86.1
Area 19	250	20.0	12.5
Totals	52,600	630.2	83.5

[1] The total number of active fishing-days is calculated to the nearest whole number from catch per unit of effo based on incompleted data and from estimated catch.

ble II.—Number of Tags Recovered by Plant Crews, According to Area of Tagging and Probable Sub-district of Recovery, for the 1953–54 Fishing Season

Area of Tagging	Tagging Code	Probable Sub-district of Recovery								Total
		Q.C.I.	Northern	Central	Upper East Coast	Middle East Coast	Lower East Coast	West Coast	?	
a 2B-E	16CC (1952)	4	2	1	—	—	—	—	1	8
	17QQ (1953)	5	—	2	—	—	—	—	—	7
	17RR (1953)	2	—	1	—	—	—	1	—	4
a 4	15T (1951)	—	63	1	—	—	—	—	8	72
	15U (1951)	—	31	3	—	—	—	—	6	40
	16Z (1952)	—	96	3	2	—	—	—	20	121
	16AA (1952)	—	121	5	1	—	—	—	28	155
	16BB (1952)	—	4	—	—	—	—	—	—	4
	17MM (1953)	1	61	—	—	—	—	—	9	71
	17NN (1953)	—	166	3	—	—	—	—	26	195
	17PP (1953)	—	125	2	—	—	—	—	28	155
a 5	9Q (1945)	—	1	—	—	—	—	—	—	1
	14CC (1950)	—	8	1	—	—	—	—	—	9
a 6	14AA (1950)	—	—	3	—	—	—	—	1	4
	14BB (1950)	—	3	14	—	—	—	—	2	19
	14DD (1950)	—	—	3	—	—	—	—	—	3
	15V (1951)	—	4	33	—	—	—	—	5	42
	15W (1951)	—	19	16	—	—	—	—	3	38
	17LL (1953)	—	23	153	—	—	—	—	28	204
a 7	8M (1944)	—	—	1	—	—	—	—	—	1
	14HH (1950)	—	—	4	—	—	—	—	2	6
	14KK (1950)	—	1	5	—	—	—	—	—	6
	15X (1951)	—	—	34	—	—	—	—	2	36
	15AA (1951)	—	—	52	—	1	—	—	3	56
	15BB (1951)	—	—	39	—	—	—	—	—	39
	16U (1952)	—	1	47	—	2	—	—	5	55
	16W (1952)	—	2	71	—	—	—	—	3	76
	16X (1952)	—	1	69	—	—	—	—	1	71
	16Y (1952)	..	..	69	.	.	.....	...	2	71
	17EE (1953)	—	1	63	—	—	—	—	5	69
	17FF (1953)	...	3	102						105
	17GG (1953)	—	3	200	—	—	—	—	25	228
	17HH (1953)	—	1	54	—	—	—	—	3	58
	17II (1953)	—	—	54	—	—	—	—	4	58
	17JJ (1953)	—	—	21	—	—	—	—	17	38
	17KK (1953)	.	1	150	1	.	.....	1	29	182
a 10	14EE (1950)	—	—	1	—	—	—	—	2	3
	15CC (1951)	—	—	6	—	—	—	—	4	10
a 12	8K (1944)	—	—	—	1	—	—	—	—	1
	9G (1945)	—	—	—	1	—	—	—	—	1
	17DD (1953)	—	—	—	83	—	—	—	12	95
a 14	14A (1950)	—	—	—	—	—	—	—	3	3
	16A (1952)	—	—	—	—	18	12	3	25	58
	17B (1953)	—	—	—	—	19	9	4	9	41
	17C (1953)	—	—	—	—	7	3	2	4	16
a 15	13A (1949)	—	—	—	—	2	—	—	3	5
	14B (1950)	—	—	—	—	4	—	—	3	7
	14C (1950)	—	—	—	—	4	1	—	4	9
	15A (1951)	—	—	—	—	10	2	—	14	26
	15B (1951)	—	—	—	—	13	4	—	25	42
	17A (1953)	—	—	—	—	13	8	2	23	46
a 17A	14E (1950)	—	—	—	—	—	—	—	1	1
	14F (1950)	—	—	—	—	1	—	—	—	1
	15C (1951)	—	—	—	—	10	—	2	7	19
	15D (1951)	—	—	—	—	—	—	—	1	1
	16B (1952)	—	—	—	—	—	1	1	—	2
	16C (1952)	—	—	—	—	1	4	—	1	6
	16D (1952)	—	—	—	1	1	2	2	2	8
	17D (1953)	—	—	—	—	—	3	—	2	5
	17E (1953)	—	—	—	—	3	3	2	1	9
a 17B	14G (1950)	—	—	—	—	—	1	—	1	2
	14H (1950)	—	—	—	—	2	1	—	—	3
	15E (1951)	—	—	—	—	2	—	—	1	3
	16E (1952)	—	—	—	—	1	2	2	3	8
	16F (1952)	—	—	—	—	1	7	2	8	18
	16G (1952)	—	—	—	—	1	9	—	1	11
	17F (1953)	—	—	—	—	1	19	2	8	30

Table II.—Number of Tags Recovered by Plant Crews, According to Area of Tagging and Probable Sub-district of Recovery, for the 1953–54 Fishing Season—Continued

Area of Tagging	Tagging Code		Probable Sub-district of Recovery								Total
			Q.C.I.	Northern	Central	Upper East Coast	Middle East Coast	Lower East Coast	West Coast	?	
	17G	(1953)	—	—	—	—	1	5	2	3	11
	17H	(1953)	—	—	—	—	—	5	2	1	8
	17I	(1953)	—	—	—	—	—	2	2	1	5
Area 18	15F	(1951)	—	—	—	—	—	7	—	8	15
	15G	(1951)	—	—	—	—	—	1	—	2	3
	17J	(1953)	—	—	—	—	1	14	7	8	30
Area 20	15DD	(1951)	—	—	—	—	1	—	—	—	1
Area 23	12K	(1948)	—	—	—	—	—	—	1	—	1
	13I	(1949)	—	—	—	—	—	—	2	—	2
	14I	(1950)	—	—	—	—	—	—	2	—	2
	14L	(1950)	—	—	—	—	—	—	1	—	1
	14M	(1950)	—	—	—	—	—	—	1	—	1
	15H	(1951)	—	—	—	—	—	—	9	—	9
	15I	(1951)	—	—	—	—	—	—	1	—	1
	15K	(1951)	—	—	—	—	—	—	1	—	1
	15L	(1951)	—	—	—	—	—	—	1	1	2
	16H	(1952)	—	—	—	—	—	—	14	—	14
	16I	(1952)	—	—	—	—	—	—	14	—	14
	16J	(1952)	—	—	—	—	—	1	53	—	54
	16K	(1952)	—	—	—	1	—	1	62	5	69
	16L	(1952)	—	—	—	—	—	1	14	—	15
	17K	(1953)	—	—	—	—	—	3	155	1	159
	17M	(1953)	—	—	—	—	—	2	59	2	63
	17N	(1953)	—	—	—	—	—	5	103	5	113
	17P	(1953)	—	—	—	1	—	2	79	—	82
	17Q	(1953)	—	—	—	—	—	2	28	2	32
	17R	(1953)	—	—	—	—	1	4	63	1	69
	17S	(1953)	—	—	—	—	—	5	80	2	87
Area 24	12M	(1948)	—	—	—	—	—	—	1	—	1
	13K	(1949)	—	—	—	—	—	—	1	—	1
	13L	(1949)	—	—	—	—	—	—	1	—	1
	15M	(1951)	—	—	—	—	—	—	6	—	6
	15N	(1951)	—	—	—	—	1	—	18	—	19
	16M	(1952)	—	—	—	—	—	—	120	2	122
	16N	(1952)	—	—	—	—	—	—	69	—	69
	17T	(1953)	—	—	—	—	—	1	49	—	50
	17U	(1953)	—	—	—	—	—	1	60	1	62
Area 25	13M	(1949)	—	—	—	—	—	—	2	—	2
	13Q	(1949)	—	—	—	—	—	—	1	—	1
	13R	(1949)	—	—	—	—	—	—	2	—	2
	13S	(1949)	—	—	—	—	—	—	2	—	2
	14Q	(1950)	—	—	—	—	—	—	2	—	2
	14R	(1950)	—	1	—	—	—	—	—	—	1
	14T	(1950)	—	—	—	—	—	—	4	—	4
	14U	(1950)	—	—	—	—	—	—	4	—	4
	15P	(1951)	—	—	—	—	—	—	7	—	7
	15Q	(1951)	—	—	—	—	—	—	20	—	20
	15R	(1951)	—	—	—	—	—	—	9	—	9
	15S	(1951)	—	—	—	—	—	—	5	3	8
	16P	(1952)	—	—	—	—	—	—	13	1	14
	16Q	(1952)	—	—	—	—	—	—	8	—	8
	16R	(1952)	—	—	—	—	—	—	12	—	12
	16S	(1952)	—	—	—	—	—	—	13	—	13
	17W	(1953)	—	—	—	—	—	—	12	—	12
	17X	(1953)	—	—	—	—	—	—	16	—	16
	17Y	(1953)	—	—	—	—	—	—	22	—	22
	17Z	(1953)	—	—	—	—	—	—	25	—	25
Area 26	14V	(1950)	—	—	—	—	—	—	1	—	1
	14W	(1950)	—	—	—	—	1	—	8	—	9
	16T	(1952)	—	—	—	—	—	1	117	1	119
	17AA	(1953)	—	—	—	—	—	—	126	2	128
	17BB	(1953)	—	—	—	—	—	—	25	—	25
Area 27	12W	(1948)	—	—	—	—	—	—	1	—	1
	12X	(1948)	—	—	—	—	—	—	3	—	3
	14X	(1950)	—	1	—	—	—	—	11	—	12
	17CC	(1953)	—	—	1	—	—	—	67	3	71
Washington State	(1)	(1953)	—	—	—	—	—	1	1	1	3
Totals			12	743	1,287	92	123	155	1,646	490	4,548

[1] These tags were put out by United States investigators in Hood Canal in April, 1953, and were recovered in the Canadian fishery.

able III.—Probable Number of Tags in the Catches during the 1953–54 Season, Based on Magnet Recoveries, Shown by Area of Tagging and Probable Sub-district of Recovery, with Actual Number of Tags in Parentheses.[1]

Area of Tagging	Probable Sub-district of Recovery							Total
	Q.C.I.	Northern	Central	Upper East Coast	Middle East Coast	Lower East Coast	West Coast	
E	17 (12)	3 (2)	4 (4)				1 (1)	25 (19)
	3 (2)	917 (789)	20 (18)	3 (3)	1 (1)			944 (813)
		10 (9)	1 (1)					11 (10)
		67 (57)	272 (252)	1 (1)				340 (310)
		16 (14)	1,219 (1,131)	4 (4)	7 (6)		1 (1)	1,247 (1,156)
			12 (11)	1 (1)	1 (1)			14 (13)
				103 (97)				103 (97)
					92 (84)	29 (25)	10 (9)	131 (118)
					124 (118)	17 (15)	2 (2)	143 (135)
5A				1 (1)	22 (20)	28 (23)	6 (6)	57 (50)
5B					12 (11)	87 (73)	17 (15)	116 (99)
					1 (1)	46 (39)	9 (8)	56 (48)
					1 (1)			1 (1)
				2 (2)	1 (1)	45 (39)	836 (723)	884 (765)
					1 (1)	4 (4)	367 (290)	372 (295)
		1 (1)				4 (3)	256 (70)	261 (74)
					1 (1)	4 (3)	301 (67)	306 (71)
7		2 (1)	1 (1)				132 (50)	135 (52)
Totals	20 (14)	1,016 (873)	1,529 (1,418)	115 (109)	264 (246)	264 (224)	1,938 (1,242)	5,146 (4,126)

[1] Tags recovered by plants in which no magnet tests were carried out were omitted in calculating the probable number of tags in the catches.

Table IV.—Average Percentage Age Composition of Samples from the Winter and Spawning Runs to the West Coast of Vancouver Island during the 1953–54 Season

WINTER RUNS

Area	Number of Samples	In Year of Age									
		I	II	III	IV	V	VI	VII	VIII	IX	X
3	51	0.04	2.88	62.60	27.74	5.93	0.53	0.15	0.09	0.02	0.02
4	12		2.03	71.33	22.26	3.51	0.78	0.09			
5A	1			67.00	30.00	3.00					
5B	3			40.52	47.25	7.94	3.83	0.46			
6	1			38.27	41.98	14.81	2.47	2.47			
7	3			47.42	40.36	10.21	0.79	1.21			
All	71	0.03	2.42	62.25	28.42	5.87	0.70	0.23	0.06	0.01	0.01

SPAWNING RUNS

3	0										
4	1		7.29	81.25	10.42	1.04					
5A	1		3.03	71.72	22.22	3.03					
5B	1			48.45	42.27	7.22	2.06				
6	0										
7	0										
All	3		3.44	67.14	24.97	3.76	0.69				

Table V.—Average Percentage Age Composition of Samples from the Winter and Spawning Runs to the Lower East Coast of Vancouver Island during the 1953–54 Season.

WINTER RUNS

Area	No. of Samples	In Year of Age								
		I	II	III	IV	V	VI	VII	VIII	IX
17A	14	—	1.37	55.78	34.40	7.50	0.71	0.16	0.08	—
17B	28	—	0.63	61.59	31.97	5.24	0.53	0.04	—	—
18	38	—	0.70	56.12	35.84	6.39	0.66	0.20	0.06	0.03
All	80	—	0.79	57.98	34.23	6.18	0.62	0.14	0.04	0.01

SPAWNING RUNS

17A	1	—	2.08	67.71	25.00	5.21	—	—	—	—
17B	1	—	4.49	49.44	38.21	7.87	—	—	—	—
18	2	—	3.03	54.55	36.36	6.06	—	—	—	—
All	4	—	3.16	56.56	33.98	6.30	—	—	—	—

Table VI.—Average Sex Ratio (Females/Males) and Stage of Development for Samples from Winter and Spawning Runs to the West Coast of Vancouver Island during the 1953–54 Season.

WINTER RUNS

Area	Sex Ratio	Percentage		
		Immature	Mature Unspent	Mature Spent
23	1.07	3.73	96.27	—
24	1.06	2.41	97.59	—
25A	1.50	—	100.00	—
25B	0.96	—	100.00	—
26	1.24	—	100.00	—
27	1.05	2.81	97.19	—
All	1.07	3.22	96.78	—

SPAWNING RUNS

23	—	—	—	—
24	1.08	—	100.00	—
25A	1.17	—	60.00	40.00
25B	0.82	—	76.00	24.00
26	—	—	—	—
27	—	—	—	—
All	1.01	—	78.67	21.33

ble VII.—Average Sex Ratio (Females/Males) and Stage of Development for Samples from Winter and Spawning Runs to the Lower East Coast of Vancouver Island during the 1953–54 Season.

WINTER RUNS

Area	Sex Ratio	Percentage		
		Immature	Mature Unspent	Mature Spent
	0.79	18.05	81.95	———
	0.82	6.49	93.51	———
	0.82	4.07	95.93	———
All	0.81	7.30	92.70	———

SPAWNING RUNS

	0.78	———	72.00	28.00
	1.04	———	18.89	81.11
	0.72	———	71.00	29.00
All	0.81	———	59.23	40.77

ble VIII.—Average Length (Millimetres) and Average Weight (Grams) for Each Age in Samples from Winter Runs to the West Coast of Vancouver Island in 1953–54, with Numbers of Fish on Which Averages are Based in Parentheses.

AVERAGE LENGTH

Year f Age	Area 23	Area 24	Area 25A	Area 25B	Area 26	Area 27	All Areas
	(2) 90.5						(2) 90.5
	(133) 161.6	(22) 154.0					(155) 160.5
	(2,935) 186.0	(749) 182.8	(67) 182.5	(101) 180.5	(31) 181.6	(127) 180.5	(4,010) 185.0
	(1,301) 200.1	(227) 198.4	(30) 198.7	(131) 197.5	(34) 198.8	(108) 198.3	(1,831) 199.5
	(279) 211.3	(35) 210.0	(3) 213.3	(21) 209.6	(12) 212.6	(27) 210.5	(377) 211.1
	(25) 223.8	(8) 218.6		(10) 221.5	(2) 225.0	(2) 226.0	(47) 222.6
	(7) 232.3	(1) 225.0		(1) 240.0	(2) 236.0	(3) 226.3	(14) 231.6
I	(4) 239.5						(4) 239.5
	(1) 271.0						(1) 271.0
	(1) 278.0						(1) 278.0
	(220) 193.0	(38) 193.9		(14) 200.4	(2) 181.0	(18) 198.7	(272) 193.06

AVERAGE WEIGHT

	(2) 8.5						(2) 8.5
	(87) 53.8	(4) 32.5					(91) 53.7
	(2,189) 86.3	(242) 78.4	Salted	(51) 77.6	Salted	(92) 77.3	(2,574) 86.0
	(879) 106.9	(45) 99.4	samples,	(117) 97.0	samples,	(284) 101.2	(1,249) 105.3
	(221) 126.9	(3) 115.7	no	(16) 122.3	no	(18) 125.2	(258) 126.4
	(20) 148.4		weights	(7) 144.6	weights	(1) 134.0	(28) 146.9
	(4) 165.8		taken		taken	(1) 145.0	(5) 161.6
I	(1) 155.0						(1) 155.0
	(166) 97.0	(6) 90.7		(9) 105.3		(10) 100.8	(191) 97.4

Table IX.—Average Length (Millimetres) in Samples from Spawning Runs to the We Coast of Vancouver Island in 1954, with Numbers of Fish on Which Averages a Based in Parentheses.

AVERAGE LENGTH

In Year of Age	Area 23	Area 24	Area 25A	Area 25B	Area 26	Area 27	All Areas
I							
II		(7) 154.4	(3) 159.3				(10) 155
III		(78) 177.5	(71) 181.7	(47) 185.5			(196) 180
IV		(10) 192.5	(22) 198.6	(41) 202.0			(73) 199
V		(1) 210.0	(3) 209.3	(7) 219.0			(11) 215
VI				(2) 233.5			(2) 233
VII							
VIII							
IX							
?		(4) 185.0	(1) 171.0	(3) 221.7			(8) 197

Table X.—Average Length (Millimetres) and Average Weight (Grams) for Each A in Samples from Winter Runs to the Lower East Coast of Vancouver Island 1953–54, with Numbers of Fish on Which Averages are Based in Parentheses.

AVERAGE LENGTH

In Year of Age	Area 17A	Area 17B	Area 18	All Areas
I				
II	(18) 152.8	(17) 150.2	(26) 152.5	(61) 152.0
III	(729) 186.1	(1,657) 187.1	(2,030) 187.7	(4,416) 187.2
IV	(445) 198.4	(858) 199.8	(1,297) 199.6	(2,600) 199.5
V	(96) 209.7	(141) 211.0	(233) 211.0	(470) 210.7
VI	(9) 218.9	(14) 225.9	(24) 222.6	(47) 222.9
VII	(2) 224.5	(1) 218.0	(7) 228.5	(10) 226.7
VIII	(1) 220.0		(2) 231.0	(3) 227.3
IX			(1) 237.0	(1) 237.0
?	(30) 193.1	(85) 196.7	(115) 196.2	(230) 196.0

AVERAGE WEIGHT

I				
II	(18) 48.4	(17) 43.9	(26) 46.5	(61) 46.4
III	(729) 90.9	(1,657) 87.7	(2,030) 88.1	(4,416) 88.4
IV	(445) 111.7	(858) 107.0	(1,297) 106.8	(2,600) 107.7
V	(96) 133.9	(141) 126.7	(233) 124.8	(470) 127.3
VI	(9) 144.6	(14) 148.0	(24) 150.6	(47) 148.7
VII	(2) 157.0	(1) 129.0	(7) 161.7	(10) 157.5
VIII	(1) 164.0		(2) 189.5	(3) 181.0
IX			(1) 186.0	(1) 186.0
?	(30) 104.3	(85) 101.2	(115) 100.2	(230) 101.1

Table XI.—Average Length (Millimetres) in Samples from Spawning Runs to the Low East Coast of Vancouver Island in 1954, with Numbers of Fish on Which Averag are Based in Parentheses.

AVERAGE LENGTH

In Year of Age	Area 17A	Area 17B	Area 18	All Areas
I				
II	(2) 157.0	(4) 150.5	(6) 161.3	(12) 157.0
III	(65) 181.9	(44) 185.9	(108) 186.6	(217) 185.0
IV	(24) 193.4	(34) 199.0	(72) 200.4	(130) 198.7
V	(5) 208.0	(7) 207.6	(12) 213.8	(24) 210.8
VI				
VII				
VIII				
?	(4) 192.5	(1) 200.0	(2) 204.5	(7) 197.0

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Recent Developments in Atlantic Salmon Research

by C. J. Kerswill [1]

Since 1950 research on Atlantic salmon on the eastern coast of Canada has expanded greatly, to provide information that should help to improve the fishery. It is a pleasure to have this opportunity of outlining for the Atlantic Salmon Association the objectives and some of the more significant results of this work. First of all the assistance provided by salmon research from 1930 to 1949 must be acknowledged. In this earlier period most of the present techniques for handling the field work were developed and fundamental information was obtained on the life history and movements of salmon associated with several rivers.

A co-ordinated programme of Atlantic salmon research is now carried on by the Fisheries Research Board of Canada through the salmon staffs of the Atlantic Biological Station, St. Andrews, N.B., and the Newfoundland Fisheries Research Station, St. John's, and by the Quebec Government through the staff of the Marine Biological Station, Grande Riviere, Quebec. It is closely associated with the salmon management programme of the Conservation and Development Service of the Federal Department of Fisheries.

To permit brief discussion of all the points believed to be of interest to the Association, eleven coloured charts were prepared for use at the Annual Meeting. Only three of these have been copied in black and white to illustrate this summary. The main features of three of the other charts dealing with salmon statistics and recent runs of salmon in the Miramichi River area accompany an article to appear in a future issue of Trade News (a Department of Fisheries publication), probably the November, 1954, issue.

* * *

FRB No. 398

1. Fisheries Research Board of Canada, Scientist in charge of Atlantic Salmon Investigation.

Regular recording of the catches of fish by various kinds of gear in all areas and the effort spent to make the catches provides one of the basic tools of fishery research. Officers of the Department of Fisheries compile such information for salmon caught in the Maritime Provinces and Newfoundland and they become available immediately to the research staff. In Quebec, salmon statistics are collected and reported by the Provincial Government.

In 1949 the system of reporting salmon catches in the Maritime Provinces was revamped, giving more complete coverage than formerly on the catches by both commercial fishermen and anglers, and on the fishing effort. Analysis of the 1949-54 statistics showed that in 1954 the total commercial landings in the Maritime Provinces were considerably higher than in the past two years. This is encouraging because there was a downward trend since 1949 when the total catch was already 3,000 hundredweights below the average total for the past 50 years which is about 20,000 hundredweights. Angling in the Maritime Provinces in 1954 reached about the same level as last year and was higher than in 1952. It is believed that it would have been much higher except for the continuously high water which interfered with angling in many areas. Both grilse and larger salmon were abundant in the Miramichi area in 1954 judging by the records at our research traps. The Miramichi contributes a large share of both the commercial and angling catch in the Maritime Provinces.

Complete statistics on 1954 salmon catches in Quebec and Newfoundland are not yet available.

Location and objectives of research projects: On the Pollett River, tributary to the Petitcodiac River, N.B., a series of planting experiments has been in progress to show the best way to use hatchery-reared fingerlings where natural reproduction is not possible. Now experimental natural spawning is under way to show the number of adults needed to give best possible smolt production. This was the site of our first conclusive bird control experiment which showed that removal of mergansers and kingfishers raised by eight times the smolt production from hatchery plantings.

Annually since 1950 on two branches of the Miramichi River, N.B., (the upper Northwest Miramichi and the Dungarvon Rivers) descending smolts have been marked

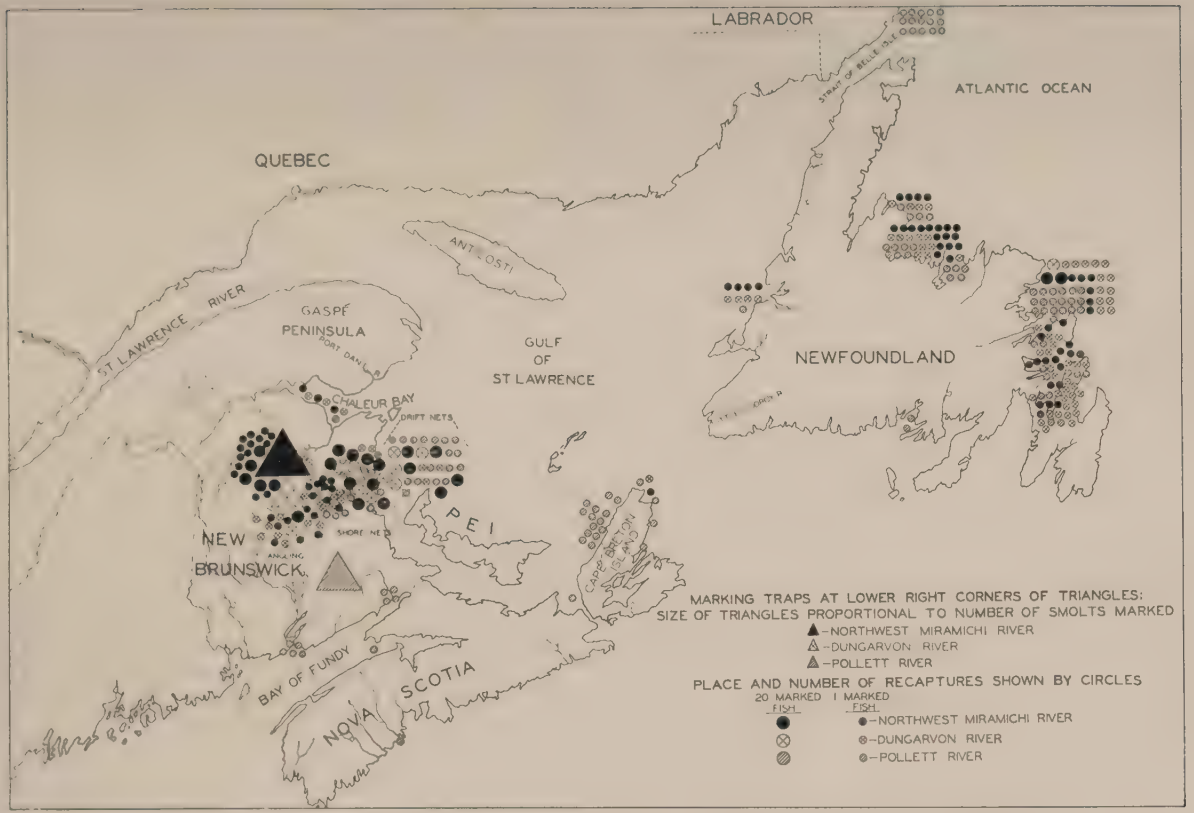

FIGURE 1. RECAPTURES BY OCTOBER, 1953, OF ATLANTIC SALMON MARKED AS SMOLTS IN 1951.

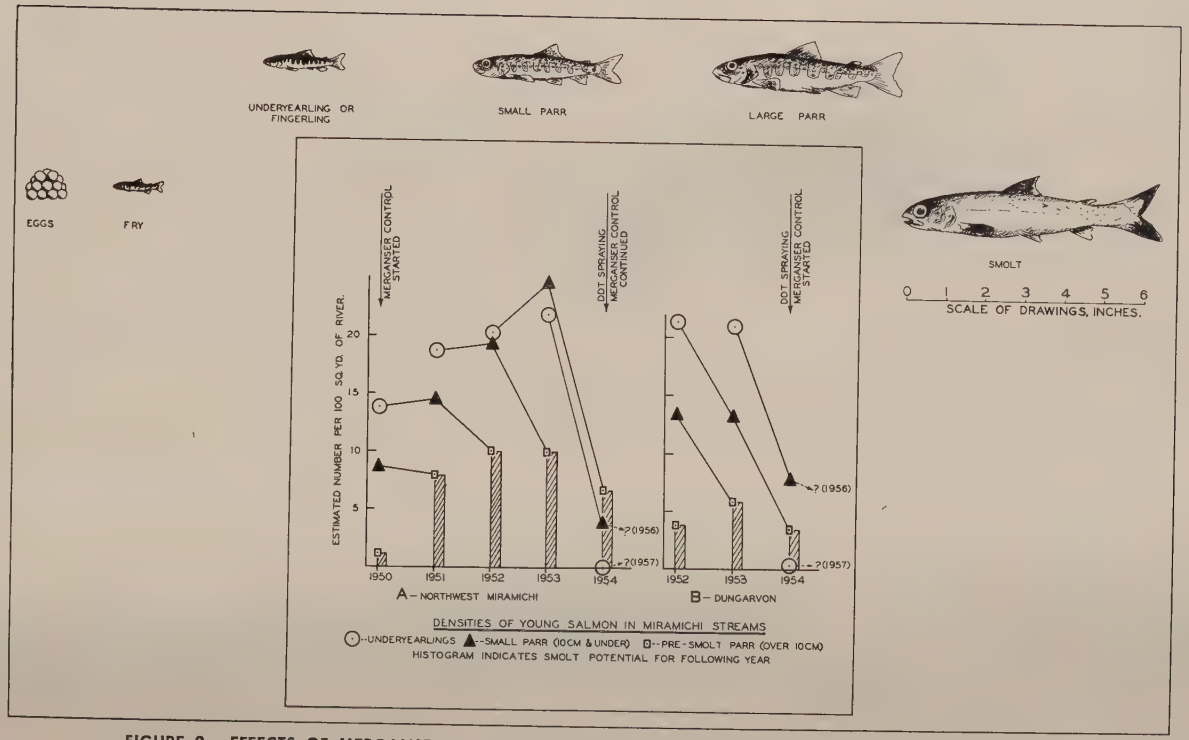

FIGURE 2. EFFECTS OF MERGANSER CONTROL AND DDT ON YOUNG SALMON, MIRAMICHI RIVER, N.B.

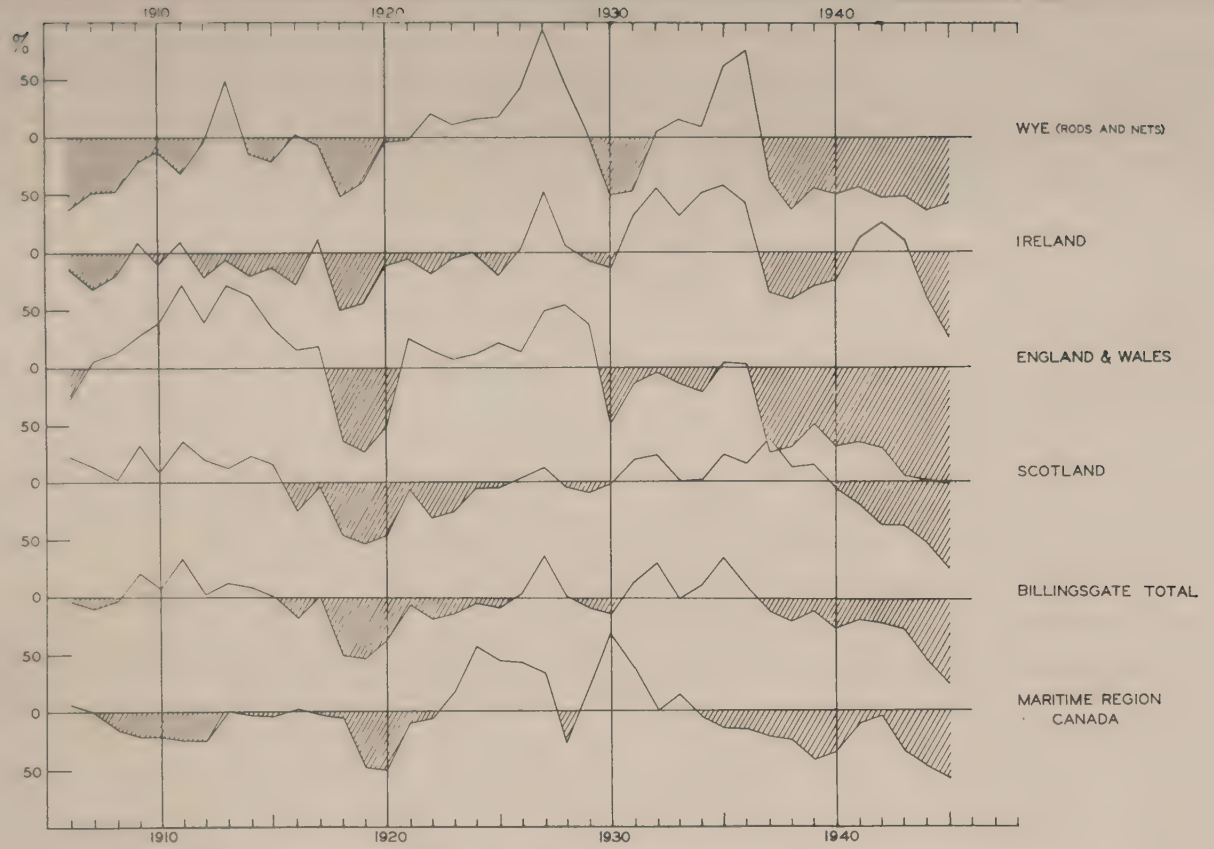

FIGURE 3. SALMON CATCHES IN BRITISH ISLES AND CANADA AS PERCENTAGES OF 30-YEAR AVERAGES, 1911-40.

at counting fences by fin clipping and an extensive search has been made later for marked adult fish over a wide area of the Atlantic coast. Marked smolts from the Pollett River plantings also contribute to this project. The purpose is to learn the utilization of salmon of known river origin by the various commercial and sport fisheries and the number spared for spawning. Smolts are sampled in the Miramichi estuary throughout the smolt run in May and June to permit estimation of the total smolt production by the Miramichi River system. Such estimates for three years range from 805,000 to 1,690,000.

On the Miramichi River ascending adult salmon are examined, counted and released annually at a sampling trap in the estuary and at the two counting fences upriver in fresh water. This provides useful information on the time and size of the various runs from year to year. Since 1950 experimental removal of mergansers has been in progress on the Northwest Miramichi and a marked improvement has been found in the survival of parr as discussed below. In 1954 experimental merganser control was extended to the whole Miramichi system in the hope of demonstrating beneficial effects on future runs and catches of adult fish. A similar experiment was started in 1953 on the St. Mary River, N.S.

Smolt marking, salmon counting and related work similar to the Miramichi operations were started in 1953 on the Port Daniel River, Quebec, and in 1954 on the Little Codroy River, Newfoundland. These streams were specially selected to permit checking all the fish leaving and entering.

* * *

In 1953 an experiment was started to show whether or not the offspring of early-run salmon return early when they become adults. Early-run fingerlings were obtained by stripping early-run adults in Rocky Brook, N.B. They are to be marked and planted in River Philip, N.B., a late-run stream, and their time of return compared with that of the local stock. The converse experiment using River Philip stock planted in the Lahave River, N.S., is to be performed also.

Recaptures of New Brunswick salmon marked as smolts: The recaptures to October, 1953, in the commercial and sport fisheries of salmon marked as smolts in 1951 at

the three marking stations are shown in Figure 1. By this time a total of 606 marked Miramichi salmon (from 48,373 marked smolts) and 133 marked Pollett salmon (from 25,187 marked smolts) had been reported. In the fresh-water part of the Miramichi system many marked Miramichi fish were taken by anglers. All the other recaptures were made in the sea by commercial gear, indicating that adult Atlantic salmon usually enter fresh water only when it is their "home" stream. Of special importance is the large number of Miramichi and Pollett salmon taken around Newfoundland by commercial fishermen. The figure shows only actual recaptures, and only about one quarter of the total Newfoundland and Labrador catch was examined for marks. All the Miramichi drift-net catch and most of the catch in other areas except the Quebec shores of the St. Lawrence were examined, so to give a true picture for the Atlantic area there probably should be four times as many dots in the Newfoundland area. Another important discovery was the large number of marked Pollett salmon caught far from the stream in which they were planted as fingerlings. This demonstrates the value of hatchery plantings in adding to the over-all Atlantic coast catch, even though few may return to the planted stream.

Weekly counts of large salmon through Miramichi fishing areas, 1954 compared to 1953: When shown graphically (see article in Trade News referred to above) the counts show considerable improvement in the availability of salmon in 1954 as compared to 1953 in the Miramichi drift-net area, the Miramichi shore net area in the estuary, and upriver in angling areas. Continuously higher water in upriver areas in 1954 handicapped angling, but the total catch was the best of the past four years. There is no indication that the 1954 postponement of both commercial and angling seasons to June 5th affected the catches significantly. Also, the local commercial fisheries do not seem to have affected the early runs of salmon available to anglers, because the fish concerned got through before sizable catches were made by commercial gear.

Effects of bird control and D.D.T. spraying on Miramichi salmon: The beneficial effects on parr survival of removing mergansers from the Northwest Miramichi River since 1950 are shown on the left of Figure 2. Three size groups

of young salmon are represented, as sketched to scale at the top. These represent the fish taken in August during an annual census by seining and electro-fishing on ten scattered sample areas. There are three size groups because three years is the commonest fresh water period for young Miramichi salmon; a few became smolts after two years, a few after four years. With mergansers controlled, the small parr (black triangles) increased from an average density of 8 per 100 square yards in 1950, to 24 in 1953. On the Dungarvon River where mergansers were not removed, (shown at the right of Figure 2) the small parr sampled on six areas averaged 13 per 100 square yards in both 1952 and 1953. Differences from year to year in the populations of fingerlings and large parr on the two tributaries corresponded to those for small parr but of course the levels of abundance were different.

In 1954 the woodland in the upper part of the Miramichi River system was sprayed against budworms with D.D.T. This had very serious direct effects on the young salmon, causing heavy mortality particularly among the fingerlings and small parr. In the sprayed streams most of the immature stages of all kinds of aquatic insects were killed also. These insects are the main food of young salmon, and some valuable kinds may not be plentiful again for years. The data for 1954 on Figure 2 show the levels of the three size groups of salmon in late August, about two months after the spraying. On both streams the fingerlings were virtually absent; small parr were reduced to $1/6$ the 1953 level on the Northwest Miramichi and to $\frac{1}{2}$ the 1953 level on the Dungarvon; large parr were reduced to $\frac{2}{3}$ the 1953 level on the Northwest Miramichi and to $\frac{1}{2}$ the previous level on the Dungarvon.

Other extensive observations on the effects of D.D.T. were made by holding parr in cages inside and outside the sprayed area and by patrolling for signs of dead and dying fish. These showed heavy mortalities among parr immediately after spraying, as well as a delayed action causing many deaths up to four months later.

Because of the observed reduction in the population of young salmon and in their food the runs of returning adult fish will be affected a few years from now. This

has a counter effect to the new bird control effort on the whole Miramichi system, but it is fortunate that the latter was introduced in 1954. With mergansers removed, the surviving parr will have a better chance to become smolts than if these predatory birds were feeding as usual.

Number of fingerlings to plant for best results: In the recent Pollett River experiments hundreds of thousands of hatchery-reared fingerlings were planted over three years on a 10-mile-long stretch of the stream. Each year the number planted was different, giving 213, 57 and 15 per 100 square yards. The heavy and medium plantings both gave an average of 16 small parr the next year which became 5 two-year smolts by the following year. The small planting gave only 4 small parr and the smolts will not be counted until 1955. It is anticipated that the best number of underyearlings to plant per 100 square yards of the Pollett for the optimum production of 5 smolts, will be about 30. Planting more is a waste of hatchery stock, and planting fewer does not take full advantage of the rearing capacity of the stream.

The number of young salmon that can be expected to live and grow well on a unit area of any stream may be smaller than many people think. It must be realized that there are two or three age groups of salmon present at the same time and usually several species of other fishes including minnows, suckers and eels. All must obtain most of their food from aquatic insects and other organisms naturally produced on the bottom of that area.

Salmon catches in the British Isles compared to our Maritime catches. In 1947 Mr. J. A. Hutton published in the Salmon and Trout Magazine (No. 119) a series of graphs showing salmon statistics for different parts of the British Isles from 1906 to 1945. The commercial landings for Ireland, Scotland, England and Wales handled at Billingsgate Market, the Billingsgate total, and the total catch by rods and nets on the River Wye for the 30-year period 1911—1940 had been averaged separately. Then the annual figures from each of the five sources for the 40-year period were plotted as percentages above and below these 30-year averages. This gave five graphs, all to the same scale. which permitted comparison of the

relative times of salmon abundance and scarcity in each fishing area. The upper part of Figure 3 is a copy of Mr. Hutton's graph. At the bottom is a graph of our total Canadian commercial landings in the Maritime Provinces for the same period, calculated in the same way.

There is a striking similarity between the ups-and-downs in our commercial salmon production and those for the other side of the North Atlantic. On the River Wye commercial fishing was abolished in 1901 and re-instituted in 1906 on a limited and strictly-controlled basis. It is interesting to note that after recovery to a peak in 1927 this fishery suffered a severe decline followed by recovery to a peak in 1936 and another severe depression from 1937 to 1945. The Canadian Maritime landings follow a pattern quite similar to that of the Wye and of the other areas.

These graphs indicate that the availability of salmon on both sides of the North Atlantic has been affected by common environmental conditions. It may be satisfying to know that our Canadian fishery is not exceptional in having suffered a depression since the late twenties. On the other hand it is realized that a concerted effort must be made now to improve conditions for salmon reproduction and survival. Recovery of the stock to more favourable levels may well be hastened by determining through research the factors limiting production during the freshwater stage of the salmon's life history. This can be followed by appropriate management procedures on the part of the Conservation and Development Service and other agencies.

Reprint from the Atlantic Salmon Journal

January, 1955

Effects of Black Salmon Angling on Miramichi Salmon Stocks

by C. J. Kerswill [1]

In 1953, 545 early-run salmon were tagged from October 21 to November 17 in Rocky Brook, a tributary of the Southwest Miramichi River. These fish had entered the stream before July 31, when access to salmon was blocked by a fence at the mouth for the rest of the season. They were stripped in the fall to provide fertilized eggs for an experiment to determine whether or not early-run salmon produce offspring which will return early when they become adults.

By midsummer, 1954, 47 (or 9%) of the tags had been turned in to the Atlantic Biological Station by black salmon anglers who caught the tagged fish between April 6 and May 15 during the regular New Brunswick black salmon season. The question has been asked "Does this not show that black salmon angling is taking too many early-run fish, believed by some to be in short supply in recent years as compared to the less valued late-run salmon?"

Two sets of data recently obtained by the salmon research staff of the Atlantic Biological Station are useful in discussing this controversial subject.

(a) *Tagging of ascending salmon, 1952.* These data comprise the recaptures by black salmon anglers in the spring of 1953, of 302 salmon (including grilse) from a total of 2,162 fish which were tagged from June to November, 1952, as they ascended the Miramichi River and were taken for brief examination at our trap in the estuary near Chatham and at our two upriver traps on the Northwest Miramichi and Dungarvon branches. The following table summarizes the tag recaptures, which have been listed according to month of tagging and month when recaptured the following spring.

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1. Fisheries Research Board of Canada, Scientist in charge of Atlantic Salmon Investigation.

	Month of Tagging						
	June	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Total*
	⟵ Mostly Early-run		—×—	All True Late-run		⟶	
Total tags applied:	230	268	58	842	659	105	2,162
Tags remaining by winter 1952-53, after 1952 fishing season:	198	236	53	826	658	105	2,076
Recovered by black salmon anglers, 1953:							
April	7	6	2	92	97	16	220
May	1	3		22	40	7	73
June				2	4	1	7
July	1			1			2
Total	9	9	2	117	141	24	302
Percentage of available tags (monthly groups) taken by black salmon anglers:	5%	4%	4%	14%	22%	23%	

The last line of the table shows that a much higher percentage (14—23%) of the fish tagged in September, October and November (true late-run salmon) were caught by the black salmon anglers than were the fish ascending and tagged earlier in the year (4—5%). This is the first time such information has been obtained for the Miramichi River, and it shows that the late-run salmon contribute greatly to the black salmon fishery.

(b) *Scale reading of large samples of Miramichi salmon.* Early studies of Miramichi salmon before 1940 indicated that a very small proportion (not over 15% and usually around 6%) of fish that had spawned once ever turned up again in any known fishery around the Atlantic coast. This agreed with the facts known about salmon in other areas including Atlantic salmon in many European rivers. Such was the biological basis for first permitting in 1939 black salmon angling in New Brunswick after a demand for it arose.

Since our new salmon investigation began in 1950 in the Miramichi River area, the life histories of many hundreds of salmon taken in our experimental traps as well as in the various commercial fisheries and by anglers have been determined by scale reading. These confirm the earlier conclusion that a very small proportion of the fish which are available to the fisheries

have ever spawned previously. A few examples are given in the following table.

Source of scale samples	*Number of fish in sample*	*Number of fish spawned previously*	*Percentage that had spawned previously*
Drift-nets off Escuminac, 1952	407	23	5.7
Drift-nets off Escuminac, 1953	251	11	4.4
Miramichi shore nets, 1953	217	10	4.6
Dungarvon R., counting fence, 1951	294	7	2.4
N.W. Miramichi counting fence, 1951	295	5	1.7

Most of the fish available to fishermen in the Miramichi area have not spawned before but are coming in from the sea for the first time since leaving fresh water as smolts. Usually over 80% of these virgin fish have passed two winters in the sea, some have spent three winters there, and they have not come back to fresh water as grilse after one summer, fall and winter at sea. Many people believe that all large salmon taken in the rivers have been there before as grilse but this is not so. Grilse are defined biologically as fish that have spent one winter in the sea, and they make up from about one-half to two-thirds the total run of fish in the Miramichi River system, the proportion varying considerably among different areas of the river.

Conclusions: Although the Miramichi black salmon fishery takes some of the early-run stock of salmon, there is small chance that these would become available again to fishermen even though they were spared. Less than 10 per cent of Miramichi salmon have come into fresh water previously for spawning. Recent tagging of incoming salmon throughout the season has shown that the proportion of the late-run fish taken by black salmon anglers in the following spring is greater then the proportion of the early-run fish taken. The black salmon fishery appears to be a worthwhile use for the late-run stock which is quite plentiful in the Miramichi area.

In weighing the merits and disadvantages of black salmon angling these points must be considered carefully, as well as the financial benefits derived from this popular sport fishery. Wanton destruction of black salmon is to be avoided, of course, since some of the largest early-run salmon in future years will be the survivors of the earlier spawning. The fishery regulations aimed at conserving black salmon should be observed carefully both by residents and by visiting anglers.

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Fish Muscle Riboside Hydrolases

By H. L. A. TARR
Pacific Fisheries Experimental Station, Vancouver, Canada

(*Received* 14 *June* 1954)

ng an investigation concerning the cause and rol of Maillard browning in heated flesh rials it was found that free ribose, in concen- ons which occasionally exceeded 0·1% of the weight, appeared when muscles of certain fishes stored at 0° or at higher temperatures. This erty was not exhibited by all fish to the same nt, but the muscles of those which were active ed ribose from added ribonucleic acid, adeno- triphosphate, ribonucleotides, ribosides and e 5-phosphate (Tarr, 1953, 1954*a*). The total ose content of the muscles of certain marine s examined has ranged from 0·1 to 0·3%, but not as yet known whether this occurs as free ic acid, as nucleic acid loosely combined with ein as in nucleotropomyosin (Hamoir, 1951*a*, *b*) some other form. Since nucleosides have not observed to be present in appreciable amounts uscles of fish which have been frozen in liquid gen while still alive, but are often present in ively high concentrations in such tissue *post em*, it would seem probable that they arise by mic degradation of nucleic acid. This suggests fish muscles contain a ribonuclease and other mes which hydrolyse ribonucleic acid to its tituent mononucleosides.

he formation of free ribose from these mono- eosides could occur by their direct hydrolysis by side hydrolase enzymes, or by nucleoside phos- olysis followed by hydrolysis of the ribose 1- phate formed. Riboside hydrolase enzymes not often been described, phosphorylative anisms apparently occurring with greater ency (Laskowski, 1951). However, Carter 1) isolated a specific non-phosphorolytic ine nucleosidase from yeast, and Lampen & g (1952) obtained both purine and pyrimidine olytic nucleosidases from *Escherichia coli*. se was not formed from either ribose 1-phos- phate or ribose 5-phosphate by these two last-named preparations. The present experiments, which have already been described briefly (Tarr, 1954*a*), have shown that fish muscles contain non-phosphorolytic nucleosidases.

EXPERIMENTAL

Materials. The nucleosides, ribose, barium ribose 5-phosphate and yeast ribose nucleic acid were obtained from Nutritional Biochemicals Corporation, Cleveland, Ohio, or from Schwarz Laboratories, Mount Vernon, New York. Cation exchange resin XE64, a finely ground form of IRC50, was purchased from Rohm and Haas Co., Philadelphia, Pennsylvania. The resin was washed and suspended in 0·2M sodium phosphate buffer as described by Hirs, Moore & Stein (1953).

Paper electrophoresis. The technique used was practically identical with that described by Kunkel & Tiselius (1951). Enzyme preparations were freeze-dried before dissolving in 0·1M veronal buffer (pH 8·6) for application in amounts not exceeding 0·05 ml. to Munktell 20S paper. The conditions used were a 16 hr. development at about 3° and 6v/cm. The papers were stained with bromophenol blue and eluted into 0·01N-NaOH as outlined by the above investigators.

Paper chromatography. Ribose was determined quantitatively by paper chromatography (Tarr, 1954*b*). Five separate 10μl. amounts of reaction mixture were applied to Whatman no. 1 papers. The papers were developed 16 hr. at 20–22° with ethyl acetate–acetic acid–water solvent (3:1:3, by vol.) (Jermyn & Isherwood, 1949) and sprayed with aniline hydrogen phthalate reagent (Partridge, 1949). The above solvent separates D-ribose from other pentose sugars (Hochster & Watson, 1954), and it was found that the pentose formed from ribosides by the enzymes to be described had an R_F value identical with that of D-ribose. Nucleosides and their corresponding purine and pyrimidine bases were determined by quantitative paper chromatography (Paladini & Leloir, 1952). Five 5μl. amounts were applied to Whatman no. 1 papers, which were developed for 3 hr. at 37° with freshly prepared ethyl acetate–acetic acid–water (3:1:1·75, by vol.) solvent. The R_F values were not

absolutely consistent with this system, but rarely varied more than $\pm 0{\cdot}02$ unit. The following R_F values were found: adenosine 0·6, adenine 0·68, guanosine 0·38, guanine 0·45, inosine 0·40, hypoxanthine 0·53, xanthosine 0·39, xanthine 0·50, cytidine 0·40, cytosine 0·51, uridine 0·56 and uracil 0·62. With guanine, xanthosine and xanthine, only a few micrograms could be applied to the paper, since overloading and consequent streaking tended to occur. Quantitative determinations were not made in these instances.

Chromatographic separation of ribose 1-phosphate and ribose 5-phosphate from ribose was carried out on Whatman no. 1 paper with *n*-butanol–acetic acid–water (1:1:0·5, by vol.) solvent. The enzyme reaction mixtures containing the pentose phosphate esters were applied in 5 μl. amounts to Whatman no. 1 paper, and were separated by ascending development with the above solvent for 8 hr. at 0°, at which temperature ribose 1-phosphate was not hydrolysed. With this system ribose 5-phosphate and ribose 1-phosphate had rather similar R_F values (0·31 and 0·37 respectively) and could be readily distinguished from ribose (R_F 0·5). The chromatograms were dried for 3 min. at 105° to remove the solvent, sprayed with aniline hydrogen phthalate reagent (Partridge, 1949) containing 0·5 ml. concentrated HCl/100 ml., and heated as usual.

Protein nitrogen. The method of Kingsley (1939) was used and was checked by micro-Kjeldahl determinations.

Enzyme preparation

Lingcod (*Ophiodon elongatus*) or rock cod (*Sebastodes* sp.) muscle from fish in rigor mortis was used. Muscle tissue which had been stored at −20° for several months also yielded satisfactory preparations. All procedures were conducted at about 0°. In a typical experiment 1·6 kg. of muscle were blended with 4·8 l. water and 204 g. of NaCl to bring the suspension to approximately 0·6 M with respect to this salt. N-HCl (240 ml.) was added slowly with rapid stirring to adjust the mixture to pH 4·6. The mixture on centrifuging at 2500 *g* yielded 4·7 l. of supernatant liquid. This was fractionated with $(NH_4)_2SO_4$ at pH 7·0. The fraction which precipitated between 0·4 and 0·6 saturation was collected by centrifuging, dissolved in water and dialysed for 2 days against repeated changes of demineralized water to yield 1·6 l. of crude riboside hydrolase containing 1 mg./ml. of protein N. Further purification was effected by treatment with cation-exchange resin XE 64 as follows.

The crude enzyme (90 ml.) was mixed with 450 ml. of wet packed XE 64 resin adjusted to pH 7·3, and the mixture kept for 30 min. at 0° with occasional stirring. The supernatant liquid was decanted, and the resin washed with fifteen successive 100 ml. portions of water by decantation. The enzyme preparation was eluted from the resin (about 450 ml.) by stirring in 66 g. NaCl (equivalent to about 2·5 M) gradually, and pouring the suspension on to a Whatman no. 4 conical filter. The resin was treated with 30 ml. of 2·5 M-NaCl and the surface then pressed firmly with a flattened glass rod to remove as much free liquid as possible. The eluate, after dialysing 18 hr. at 0° against several changes of demineralized water, measured 168 ml. and had 0·016 mg. protein N/ml. Analyses of the resin supernatants, washings and eluates in this and similar preparations showed that at least 95 % of the protein N initially present in the crude enzyme used could be accounted for. These resin eluates have been referred to as purified enzyme preparations. Neither crude nor purified enzyme preparat form ribose in absence of added nucleoside.

Experimental conditions. Unless otherwise stated, nucleosides were used in 0·0133 M final concentra (equivalent to 2 mg./ml. of ribose), and were heated effect solution where necessary. Xanthosine solutions adjusted to pH 7. Enzyme reactions were carried ou small stoppered tubes containing 0·1 ml. each of nucleo and buffer solutions and 0·2 ml. of enzyme preparat The sodium phosphate and sodium acetate buffers used 0·2 M with respect to the cations, and sodium veronal bu 0·1 M with respect to diethylbarbituric acid.

RESULTS

Recovery and relative activities of enzyme prepa tions. The relative activity and recovery obtai with such preparations could not be assessed accurately for there were considerable variation their power to hydrolyse different ribosides. calculations were also somewhat complicated the facts that whole muscle contains undetermi amounts of ribosides, and its riboside hydro activity did not appear to be noticeably affected pH, as is the case with the enzyme preparati Thus with whole lingcod muscle, ribose forma with and without added inosine was found t similar at natural pH (6·6) or at pH 5·7. The d given in Table 1 show that one purified prepara hydrolysed guanosine over 1500 times as acti on a protein basis as did whole muscle, but that purification procedures, especially that involv the ion-exchange resin, resulted in very recoveries.

Electrophoresis experiments. Paper electrophor showed that crude riboside hydrolase preparat yielded two (and occasionally three) protein zo while purified preparations yielded only a si zone which did not move appreciably from the p of application. This suggested that riboside hy lase activity may be associated with a protein w does not migrate appreciably by either elec phoresis or electro-osmosis under the experime conditions. However, although inosine was hy lysed actively by preparations which had b applied to filter papers moistened with 0·1 M sod veronal buffer pH 8·6, even after these had b stored several days at 0°, the enzyme activity rapidly lost on the application of an electric poter (4–6 v/cm.). The reason for this loss of activity not yet been established.

pH–*Activity relationship.* Crude preparat hydrolysed the four purine ribosides and cytid but not uridine, ribonucleic acid or ribonucleoti at pH 5·6. On the other hand, at pH 8·6 inosine the only riboside which was hydrolysed app ably, though some crude preparations, which tained an active adenosine deaminase, also for ribose from this substrate. The results obtaine a typical experiment are shown in Table 2.

Table 1. *Comparative activity and recovery of riboside hydrolases*

nded whole muscle (3 g.) at natural pH 6·6 + nucleoside solution or water (1 ml.) formed the following amounts of in 1 hr. at 37°: control, 220; guanosine, 290 and inosine, 620 μg./g. (1 g. ≃ 26 mg. protein N). The crude enzyme g. protein N ml. final concentration) formed 1700 μg./ml. of ribose from guanosine and 1000 μg./ml. from inosine in at 37° in 0·1 M acetate buffer pH 5·0. The freeze-dried purified preparation (0·04 mg. protein N/ml.) formed 1070 μg./ ribose from guanosine and 1060 μg./ml. from inosine in 3 hr. at 37° in 0·1 M acetate buffer pH 5·5, while the other ed preparation (0·005 mg. protein N/ml.) formed 520 μg./ml. of ribose from guanosine in 6 hr. under similar conditions. er crude nor purified enzyme preparations formed ribose in absence of added nucleosides.

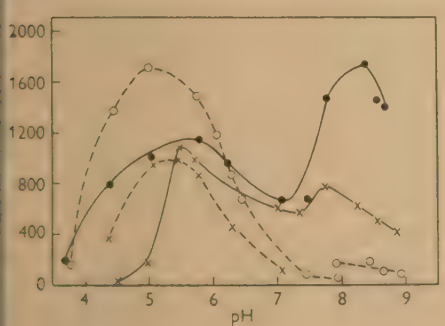
Preparation studied	Ribose (μg.) formed in 1 hr. at 37° by 1 mg. of protein N*		Ribose (mg.) formed by 100 g. of original muscle or by the quantity of enzyme recovered from that amount of muscle†	
	Inosine	Guanosine	Inosine	Guanosine
Muscle	23·8	11·1	38·8	82·9
Crude enzyme	666 (28)	1134 (102)	28·4 (73)	16·6 (20)
Purified enzyme (freeze-dried)	8830 (370)	8930 (805)	4·2 (10·8)	4·12 (4·97)
Purified enzyme (not freeze-dried)	—	17 400 (1582)	—	4·70 (5·67)

*The figures in parentheses refer to the increase in activity in terms of that of the whole muscle.
†The figures in parentheses denote the actual percentage of the initial riboside hydrolase activity of the muscle which be accounted for in given enzyme preparations.

e 2. *Hydrolysis of ribosides at different* pH *values by a crude enzyme preparation*

ditions: 0·46 mg./ml. protein N; 0·1 M phosphate pH 5·6 or 0·05 M veronal buffer pH 8·6; incubation erature 37°.

	Ribose (μg./ml.)			
	Initial pH 5·6		Initial pH 8·6	
	1 hr.	2 hr.	1 hr.	2 hr.
lenosine	490	820	50	110
anosine	800	1130	50	50
osine	520	850	380	1020
anthosine	230	180	0	0
tidine	160	175	0	0



. pH/Activity curves of riboside hydrolase prepara- s with guanosine and inosine as substrates. Crude yme, inosine (●—●); purified enzyme, inosine —×); crude enzyme, guanosine (○– – –○); purified yme, guanosine (×– – –×). Crude enzyme, not freeze- d. 0·5 mg. protein N/ml.; purified enzyme, freeze- d. 0·04 mg. protein N/ml. Incubation period 3 hr. at . Buffers: pH 3·7–5·5, 0·1 M acetate; pH 5·5–7·8, M phosphate; pH 7·8–9·0, 0·05 M veronal.

Further experiments with crude and purified preparations confirmed and extended these initial findings. Fig. 1 shows the pH/activity curves which were obtained when crude and purified enzyme preparations hydrolysed guanosine and inosine. Guanosine was hydrolysed most actively at pH 5·0 by the crude preparations, and at pH 5·5 by the purified enzyme preparations. No hydrolysis of this riboside occurred at pH values above 7 with the purified enzyme, though the crude enzyme exhibited slight activity in this region. With inosine as substrate both the crude and purified preparations exhibited two pH optima, one in the acid and the other in the alkaline region. This indicated that the purified riboside hydrolase preparations possessed two distinct enzymes, one which hydrolysed inosine with a pH optimum of about 8, and another which hydrolysed purine ribosides and cytidine and having a pH optimum of about 5·5. With purified enzyme preparations hydrolysis proceeded at approximately the same rate in phosphate or acetate buffers at pH 5·5, and in veronal or phosphate buffers at pH 8·0, and it therefore was concluded that the type of buffer had no important effect on the pH–activity relationship.

Substrate specificity. The substrate specificity of purified enzyme preparations was studied at both acid and alkaline pH optima. Lingcod muscle itself hydrolyses uridine (Tarr, 1954*b*), and since neither crude nor purified enzyme preparations from this source do this, it would seem likely that the muscle possesses a uridine hydrolase which is distinct from the present enzymes. The results of an experiment in which single ribosides and mixtures of ribosides were hydrolysed with a purified enzyme preparation at pH 5·5 are given in Table 3. They

Table 3. *Ribose formation from single ribonucleosides and from mixtures containing equal amounts of two ribonucleosides at* pH 5·5

Protein N 0·033 mg./ml.; 0·1 M acetate buffer pH 5·5; 3 hr. incubation at 37°.

Substrate	Ribose concentration in nucleosides (mg./ml.)	Ribose formed (μg./ml.)	Theoretical amount of ribose assuming that both ribosides were hydrolysed independently (μg./ml.)
Adenosine	2	490	—
Adenosine	4	620	—
Inosine	2	470	—
Inosine	4	580	—
Guanosine	2	600	—
Guanosine	4	790	—
Xanthosine	2	150	—
Xanthosine	4	160	—
Cytidine	2	100	—
Cytidine	4	160	—
Uridine	2	0	—
Uridine	4	0	—
Adenosine + inosine	4	570	960
Adenosine + guanosine	4	510	1090
Adenosine + xanthosine	4	510	640
Adenosine + cytidine	4	505	590
Adenosine + uridine	4	360	490
Inosine + guanosine	4	570	1070
Inosine + xanthosine	4	500	620
Inosine + cytidine	4	500	570
Inosine + uridine	4	280	470
Guanosine + xanthosine	4	520	750
Guanosine + cytidine	4	660	700
Guanosine + uridine	4	560	600
Xanthosine + cytidine	4	180	250
Xanthosine + uridine	4	170	150
Cytidine + uridine	4	50	100

Table 4. *Ribose formation from single ribonucleosides and from mixtures containing equal amounts of two ribonucleosides at* pH 8·6

Protein N 0·063 mg./ml.; 0·1 M veronal buffer pH 8·6; 4 hr. incubation at 37°.

Substrate	Ribose concentration in nucleoside(s) (mg./ml.)	Ribose formed (μg./ml.)
Adenosine	2	0
Adenosine	4	0
Inosine	2	260
Inosine	4	350
Guanosine	2	0
Xanthosine	2	0
Cytidine	2	0
Uridine	2	0
Inosine + adenosine	4	< 25
Inosine + guanosine	4	255
Inosine + xanthosine	4	275
Inosine + cytidine	4	260
Inosine + uridine	4	245

indicate that nucleoside hydrolysis in the acid pH range is probably due to a single enzyme since in no instance did a mixture of two different nucleosides yield the amount of ribose which would be expected if separate enzymes were involved. In fact, in almost every instance the amount of ribose formed from a mixture of two ribonucleosides was slig less than that formed from any single riboside a 4 mg./g. ribose equivalent level. The existenc this competitive effect, and lack of an additive would lend support to the assumption that enzyme which has a pH optimum of about 5 a non-specific purine and pyrimidine nucle hydrolase.

The substrate specificity of the enzyme which a pH optimum of about 8·0 was quite differen hydrolysed only inosine, and this hydrolysis almost completely inhibited by adenosine, and by other purine ribosides (Table 4). It is ther a specific inosine hydrolase.

Temperature–activity relationship. Fish m acid riboside hydrolase is active over a wide r of temperatures. The action was comparatively between 0 and 20°, but increased markedly a 20° as is shown in Table 5. At 50 and 55° hydr was very rapid but the enzyme soon becam active.

Proof that direct hydrolysis of ribosides oc Purified riboside hydrolase was incubated various ribosides at pH 5·5, and the simultan appearance of both free ribose and the correspo bases was determined qualitatively and, in se

ances, quantitatively by paper chromatophy. The qualitative tests showed that hydrolysis a given ribonucleoside was accompanied by ultaneous formation of free ribose and the responding purine or pyrimidine base. Table 6 ws that the amount of ribose which appeared on lrolysis was, in those instances tested, about uivalent to that which was calculated from the ntity of purine or pyrimidine formed.

A purified freeze-dried riboside hydrolase preation (0·06 mg. protein N/ml.) was incubated r. at 37° in 0·05 M veronal buffer pH 8·6 or in M acetate buffer pH 5·5 containing 2 mg./ml. of ose 1-phosphate or ribose 5-phosphate, or 4 mg./ of inosine. The reaction mixtures were analysed ribose and for the ribose phosphates by paper omatography. The preparation hydrolysed inoat pH 5·5 (2200 μg./ml. of ribose) and at 8·6 (590 μg./ml. of ribose). However, no ribose uld be detected when amounts of reaction xtures equivalent to 20 μg. of ribose 1-phosphate ribose 5-phosphate were chromatographed at 0° described above. Since the reagent used to spray chromatogram allows the detection of 0·25 μg. ribose, it was concluded that purified riboside lrolase does not hydrolyse either of the ribose sphate esters. This indicates that the enzyme is rue hydrolase and that phosphorolysis of the osides is not involved. The fact that purified parations which have been thoroughly dialysed inst demineralized water hydrolyse ribosides ually well in acetate or phosphate buffer of the same pH values also indicates that these enzymes are strictly nucleoside hydrolases.

Isolation of D-*ribose and xanthine.* Guanosine (500 mg.) was incubated at 37° with 40 ml. of crude riboside hydrolase containing 1·5 mg. protein N/ml. The mixture was adjusted to pH 5·0 with 0·2 N-HCl and was stirred gently, the pH being kept between 5·0 and 5·5 by regular addition of HCl. After 10 hr. the pH did not rise appreciably, and quantitative chromatographic analysis indicated that approximately the theoretical amount of ribose was present (265 mg.). The mixture was brought to pH 4·6, chilled to 0°, and the precipitate of protein and purine base removed by centrifuging at 0° and 14 000 *g*. The precipitate was suspended in 20 ml. of water and the centrifuging repeated. The clear supernatant fluids were pooled, freeze-dried, and the dry residue extracted by shaking mechanically with four successive 25 ml. portions of 99 % ethanol. The clear filtrate was dried *in vacuo* over H_2SO_4 and ribose diphenylhydrazone prepared from the residue by the method of Mandl & Neuberg (1952). Crude ribose diphenylhydrazone (364 mg., m.p. 142°) was obtained in 65 % of the theoretical yield. The crude material was recrystallized from hot chloroform and its characteristics were compared with those of similarly crystallized ribose diphenylhydrazone prepared from an authentic sample of D-ribose. (Mixed m.p. and m.p. of authentic and unknown 137–138°; C, 64·66; H, 6·50. Calc. for $C_{17}H_{20}N_2O_4$: C, 64·54, H, 6·37 %. The following values were found for $[\alpha]_D^{22}$ in methanol.

Table 5. *Temperature activity relationships of a purified riboside hydrolase preparation*

0·044 mg. protein N/ml.; 0·05 M phosphate buffer pH 5·6.

	Ribose (μg./ml.)					
	Guanosine			Inosine		
Temp. (°)	1 hr.	2 hr.	4 hr.	1 hr.	2 hr.	4 hr.
20	50	—	120	60	—	140
25	140	—	300	185	—	200
30	145	—	500	180	—	310
37	180	460	1120	—	230	580
45	270	610	920	—	330	570
50	310	560	—	—	400	—
55	500	505	—	220	505	—

Table 6. *Hydrolysis of ribosides with simultaneous liberation of purine or pyrimidine base and of ribose*

Ribosides 0·0266 M, purified enzyme 0·1 mg. protein N/ml., 0·1 M acetate buffer pH 5·5, 37°.

Substrate	Time (hr.)	Corresponding base found (μg./10 μl.)	Ribose	
			Found (μg./10 μl.)	Calc. (μg./10 μl.)
Adenosine	1	6·97	8·00	7·75
	2	9·53	12·68	10·6
	4	23·7	30·4	26·3
Inosine	1	3·68	4·24	4·05
	2	14·8	15·2	16·3
Xanthosine	2	8·2	7·10	8·09
Cytidine	2	7·7	8·00	11·4

Table 7. *Stability of freeze-dried riboside hydrolase*

Enzyme corresponded to 2 ml. purified preparation. To this was added 0·2 ml. inosine (equiv. to 4 mg./ml. ribose) and 0·2 ml. 0·2M acetate buffer pH 5·5. 2 hr. incubation at 37°.

Storage conditions		Ribose formed from inosine
Days	Temp. (°)	(μg./ml.)
1	−20	1180
1	0	1190
1	20	1050
18	−20	1110
18	0	1130
18	37	1035

Authentic: initial, −3·81°; 24 hr., −7·27°; 48 hr., −3·1°. Unknown: initial, −5·37°; 24 hr., −7·70°; 48 hr., −3·8°.)

The residue from the ethanol extraction was shaken several hours at room temperature with 10% NH_4OH (v/v) and the insoluble residue removed by centrifuging. The supernatant liquid was evaporated *in vacuo* over H_2SO_4 to yield 280 mg. of a dry, white residue, which had an absorption spectrum in the ultraviolet region similar to that of xanthine. The purity was only 55% as calculated from the molar extinction coefficient in 0·1N-NaOH at 285 mμ. This represented 57% of the theoretical amount, assuming both complete hydrolysis of the guanosine and deamination of the guanine formed. The crude material was stirred for 1 hr. with 25 ml. N-HCl, filtered with suction and the filtrate adjusted to pH 7 with 2·5N-NaOH. The white crystalline material which formed on standing overnight at 0° was collected on a sintered glass filter, washed with water, and dried over P_2O_5 *in vacuo* (yield 120 mg.). This material, when dissolved in 0·1N-NaOH, had an ultraviolet extinction coefficient at 285 mμ. characteristic of xanthine. $\epsilon^{10^{-4}}_{calc.}$ 0·99, found 0·92 (93%) (Stimson & Reuter, 1943, Hotchkiss, 1948). The following absorption ratios were found: 290/280 = 0·87, 250/260 = 1·08, 280/250 = 1·96; literature values for xanthine 0·91, 1·12 and 2·04 respectively (Hotchkiss, 1948).

Stability of freeze-dried preparations. A purified preparation which had been dialysed 18 hr. against demineralized water and which was not quite free from sodium chloride was freeze-dried in 2 ml. portions in small vials which were sealed and stored at four different temperatures. The results of activity tests (Table 7) indicate that freeze-dried preparations are fairly stable for short periods. No prolonged storage tests have yet been made. Tests indicate that the presence of a trace of NaCl in these preparations improves their stability.

SUMMARY

1. A method of preparation of crude riboside hydrolase enzymes from muscles of certain marine fishes is described. The muscle is extracted with co 0·5–0·6M-NaCl or KCl at pH 4·6 and the extra fractionated with $(NH_4)_2SO_4$ at pH 7, the fracti obtained between 0·4 and 0·6 saturation possessi most of the activity.

2. Crude preparations were purified by stirri with Amberlite cation-exchange resin XE 64 at p values slightly above 7, eluting with NaCl a dialysing.

3. Crude preparations contained two (a occasionally three) proteins as judged by zo electrophoresis while purified preparations show a single protein zone.

4. The purest preparation obtained hydrolys guanosine over 1500 times as actively as did wh muscle on a protein N basis.

5. Purified preparations contained two distir enzymes, a non-specific riboside hydrolase w a pH optimum of about 5·5 which hydrolys purine ribosides and cytidine, and a specific inosi hydrolase with a pH optimum of about 8·0. Th enzymes were not separated. Neither ribose phosphate nor ribose 5-phosphate was hydrolys and nucleoside hydrolysis proceeded in the abser of added inorganic phosphate.

6. D-Ribose diphenylhydrazone and xanthi were isolated from a reaction mixture of guanos and crude riboside hydrolase.

7. The enzyme preparations withstood free drying and were active even at 55°.

I am indebted to Dr Herman Kalckar for a sample barium ribose 1-phosphate, and to Dr D. R. Idler determinations of carbon and specific rotations.

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ON THE EARLY DEVELOPMENT OF *PORROCAECUM DECIPIENS*

The eggs of a marine ascarid, *Porrocaecum decipiens* (Krabbe), are laid in the stomachs of seals (Scott, 1953, J. Fish. Res. Bd. Canada. 10: 539–547) and pass out to the sea in the feces of seals. As part of an investigation on the life cycle of *P. decipiens*, some simple experiments were carried out to determine if the eggs of this parasite would hatch in sea water. The work was sponsored by the Fisheries Research Board of Canada and done in August, 1949, at the Atlantic Biological Station, St. Andrews, New Brunswick, under the direction of Dr. W. R. Martin.

Three gravid female worms were taken from the stomach of an experimentally-infected harbor seal, *Phoca vitulina* (Linnaeus). The uteri of the worms were removed and about 100 eggs were taken from the vaginal end of each uterus. The three lots of eggs were thoroughly mixed together, and from this mixed lot about 50 eggs were placed in each of three Syracuse watch-glasses. Sterile conditions were not provided.

Each lot of eggs was kept at a different temperature: one in darkness at 2° to 4° C., and a second in darkness at 13° to 14° C.; these temperatures fall within the range of temperatures to which the eggs of *P. decipiens* might ordinarily be exposed in the sea. The third lot was kept on the author's desk and was exposed to normal daily light changes and to a wide range of temperatures (about 17° to 25° C.) which would not be commonly encountered by the eggs of *P. decipiens* under natural conditions.

The eggs adhered firmly to the bottom of the watch glasses; this permitted daily changes of sea water without any loss or undue disturbance of the eggs. Examinations of the eggs were made at intervals of 24 hours or less.

The eggs had begun to develop when they were removed from the uteri. Although a few eggs in the 16-cell stage were seen, most were in the 4-cell stage. At this stage the eggs were almost spherical; the average dimensions of 10 eggs were 52 microns in length by 45 microns in width.

Development at 2° to 4° C. was very slow; indeed, it was so slow that only the absence of degenerative changes indicated that the eggs were still alive. The morula stage was first observed by the end of four days and the gastrula stage was not reached until 18 days had elapsed. By the end of the experiments after 27 days no movements of larvae within the eggs had been detected.

At 13° to 14° C. development was much more rapid than that observed at 2° to 4° C. The morula stage was present after three days and gastrulae were noted by the end of the fifth day. Movement of some embryos was observed after seven days. Some eggs hatched after 13 days; the remainder of this lot had hatched by the end of the 14th day. After hatching the larvae remained close to the empty eggs and became fixed by their posterior ends to the bottom of the watch glass. The larvae were very active, wriggling and gyrating about a vertical plane. Once they had become attached to the bottom, they remained in this position and did not move horizontally along the bottom of the dish. Ten larvae averaged about 200 microns in length at this time. Little anatomical detail could be seen: a small boring tooth was visible; anteriorly the esophagus and ventriculus were differentiated, but the rest of the digestive system was not clearly defined. The newly-hatched larvae were encased in loose-fitting sheaths, which probably were the moulted cuticles of the first-stage larvae. Although the larvae remained fully active until the end of the experiments, 13 days later, no larva was able to get rid of the old cuticle.

The most rapid development occurred at 17° to 25° C. The morula stage was reached after two days, gastrulae were observed after three days, and movement of some embryos was noticed after four days. Hatching began for some individuals as early as the 8th day and was completed for the whole group by the end of the 9th day. Following hatching, all worms died, apparently within a few hours. Although the actual process of hatching was not observed in this group, many empty egg-shells were seen closely associated with amorphous masses of dark material which were presumably the remains of dead larvae. In a few cases amorphous material was also seen extending from within the egg to the outside as though the larva had died during hatching. The cause of the complete mortality of this group is unknown.

Apart from the direct relationship between temperature and the rate of development, two main conclusions can be made from these experiments. First, the eggs of *P. decipiens* can hatch in sea water at temperatures of 13° to 14° C., they hatched into second stage larvae. Secondly, the larvae were unable in 13 days to free themselves from the old cuticle of the first larval stage; from this it is inferred that entry into some intermediate host is probably necessary before the first cuticle can be dissolved.—D. M. SCOTT, *Atlantic Biological Station, St. Andrews, N. B. and Department of Zoology, University of Western Ontario, London, Ontario, Canada.*

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The Hydrography of Hudson Bay

By H. B. HACHEY, F.R.S.C.

oduction

he only detailed examination of the hydrography of the Hudson Bay on was made by the author in 1930, and in publishing the results achey, 1931), the earlier knowledge of the hydrography was reviewed. e 1930, our knowledge of these waters has been supplemented chiefly he observations made by ships of the Royal Canadian Navy in 1948 iley and Hachey, 1951), and by the annual investigations initiated 947 by the Fisheries Research Board of Canada (M. J. Dunbar, 1951). ummary of our knowledge of Eastern Arctic waters generally is given M. J. Dunbar (1951).

dson Bay a Large Estuary

haracteristically, Hudson Bay is an estuary, as indicated by the intense ity stratification in summer in the upper twenty-five metres of water. face salinities in the open bay may be as low as 23 0/00, and salinities wenty-five metres lower than 31 0/00, with this intensity of stratification reasing from James Bay to open waters of Hudson Strait.

he horizontal salinity gradient is most intense as it is followed from mouth of James Bay, with a surface salinity of less than 23 0/00 to seaward end of Hudson Strait where the surface salinity is 32 0/00 higher.

he temperature stratification reaches a peak in September and is fly contained within the upper twenty-five metres. Recorded surface peratures in the open bay have been as high as 9.5°C., and tempera- s at twenty-five metres ranged from —1.8°C. to 1.5°C. in August, 0 (Hachey, 1931), and from 0.6°C. to 7.8°C. in September, 1948 iley and Hachey, 1951). The marked salinity stratification of the face layer of Hudson Bay in summer which gives it the character of an ary is wholly contained within the upper fifty metres.

dson Bay an Inland Sea

n extent, Hudson Bay is an inland sea. Its area is about 200,000 square s (520,000 sq. km.), with an average depth of about 90 metres, and aximum depth of about 256 metres. It is completely enclosed on three ds, with a major opening to the northeast, 100 miles (161 km.) in

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width, leading into Foxe Channel and Hudson Strait. A minor openi Roes Welcome Sound, also leads into Foxe Channel. The characteris of the deeper waters of the Bay are oceanic in that the salinities are th of the open ocean.

The General Circulation

The general circulation of Hudson Bay proper has been dealt with earlier publications (Hachey, 1931 and 1935; Dunbar, 1951; Cana Dept. Mines and Technical Surveys, 1954). In general, the circulation anticlockwise, with a southward flow on the west side and a northwa flow on the east side of the Bay. The predominant movement in the surf waters is from James Bay northward along the eastern shore, holding cl to the coast.

The outward flow from Hudson Bay is evident as a dominant easte set along the northern side of Digges Island at the western end of Hud Strait on the south side, which constitutes a constantly outward curre An inward movement of water along the northern side of Hudson Str is indicated by the drift of icebergs, which are commonly found beyo Big Island to the north and midway through the Strait, and upon occas found in Hudson Bay itself.

The ice movements from Foxe Channel, which take place on a la scale, are indicative of the movements of more northerly water into Hud Bay and Strait. Tidal observations in Fisher Strait, south of Southamp Island, have indicated a preponderance of flow southwestward.

In 1930, five hundred drift bottles were released in Hudson I (Hachey, 1935). The experiment was remarkable in the number returns, and in the fact that the returns have continued even to the pres year. Ten per cent of the bottles were recovered, and from one lot, per cent. The returns were heaviest in 1931, when twenty-two were ceived, and gradually decreased until 1936, when only two were report In each of the years 1938, 1939, 1942, 1945, 1950, 1952, and 1953, drift-bottle return was received. All the bottles recovered were taken fr within the Bay, and the plotted probable courses of these bottles conf the anticlockwise circulation of the waters.

The Tides in the Hudson Bay Region

Details of the tides in the Hudson Bay region are published annu by the Canadian Hydrographic Service (Canada Dept. Mines and Tech cal Surveys, 1954). In Hudson Bay the rise of the tide from datum ran between 1½ and 2½ feet at Port Harrison on the east coast, to betw 11½ and 15 feet at Churchill on the west coast.

In Hudson Strait the mean rise of the tides from datum ranges betw 8 and 11½ feet at Digges Island at the inner end of the Strait, to betw 31½ and 41 feet at the mouth of the Koksoak River at the head of Ung Bay. Recent observations in the Koksoak River area have, it is believ

orded tides higher than any in the world, exceeding even those of the y of Fundy.

asonal Cycle in the Surface Layer

The hydrographic data available for Hudson Bay are almost wholly ated to the months of August and September, and these data indicate it the seasonal changes in temperature and salinity take place almost olly within the upper fifty metres, which for our purposes constitute surface layer.

During the winter months, Hudson Bay is completely ice covered, with exception of "leads" of open water, which vary in extent and position Hare and Montgomery, 1949). While no data are available on the inity of the water under the ice, on the average, for the upper fifty tres, it might be estimated as 30 0/00, with a temperature of approxiitely —1.6°C. With the advent of spring, the "break-up," movement d melting of the ice cover, and increase in drainage from the land, there a lowering of the salinity of the immediate surface waters, and this is beginning of the stratification which develops in the upper layer. The vering of the salinity continues with the extended period of the break-up the ice, a period which is prolonged through the blocking of Hudson ait by the ice from Foxe Channel. Gradually, as the ice disappears, the mediate surface water temperatures increase and temperature becomes a tor in furthering stratification in the upper layer. The process of heating d freshening is eventually carried down to a depth of approximately y metres, the maximum stratification probably occurring in early ptember. In September, the heat losses exceed the heat gained and face temperatures decrease. Decreasing surface temperatures bring out increased surface densities and initiate a process of vertical mixing, hich is accelerated by wind and wave action. Finally the "annual overn" has been completed, extending probably to depths of fifty metres, d the whole layer is at a temperature which approximates the freezing int of these waters.

e Deeper Waters

Below fifty metres, and extending in places to depths of more than two ndred metres, is a cold saline body of water with temperatures ranging nerally between —1.0°C. and —1.8°C. and with salinities ranging between .00 and 33.50 0/00, which seemingly undergoes very little change from son to season or from year to year. As shown by Bailey and Hachey 951), the small changes in temperature and salinity of these deeper ters that have been noted between 1930 and 1948 may be of considerle significance in indicating the varying intensity of the "Atlantic inence" on more northerly waters. The magnitude of this "Atlantic luence" is of considerable interest to the Greenland cod fishery. This hery presumably exists at the present time because of the stronger

"Atlantic influence" of recent years, which is responsible for water tempe tures suitable to the cod.

The question of the replacement of these deeper waters is of func mental interest. It is axiomatic that where fresh water from continen drainage mixes with saline ocean waters, the light water is dispersed fr the area of mixing. As this process in nature is more or less continuo although varying in intensity, there must always be a renewal of the m saline waters in the mixing area. If the cold, saline body of water bel fifty metres in Hudson Bay is involved in such a mixing process, then th must be a renewal on some scale, however small. Otherwise, enclosed it is in a deep basin, with only a comparatively narrow submarine exit Hudson Strait, this body of cold saline water is dynamically dead. A co parison of the waters of Hudson Bay in 1930 and 1948 (Bailey a Hachey, 1951) has shown that the characteristics of this cold saline bo of water below fifty metres were, in the respective years, as follows:

1930: temperatures of —1.8°C. with salinities between 31.50 a 33.17 0/00.

1948: temperatures less than —1.0°C. with salinities between 32. and 33.50 0/00.

These observed variations at least indicate a replacement or renewal the deeper waters of Hudson Bay on some scale, however large or small.

It is improbable, because of the lower salinities observed in the up fifty metres in the late summer, that the deeper waters of Hudson Bay involved in the "annual overturn" within the bay, that process bei brought about by the cooling and sinking of surface waters. The lov temperatures of waters below fifty metres can, with our present knowled only result from surface chilling, but the comparatively high salinit associated with these lower temperatures suggests that such surface chilli must have taken place outside of the Bay, either in Foxe Channel or Fo Basin or even in Hudson Strait. Such reasoning implies that replacem of these deeper waters within the Bay takes place only in the colder mont for only at such times is there possibly a source of water of such char teristics in Hudson Strait and Foxe Channel. An examination of publish data (Hachey, 1931; Bailey and Hachey, 1951) for the months of Aug and September will show that salinities of 33 0/00 or greater in Huds Bay are associated with temperatures of —1.0°C. or lower, while Hudson Strait such salinities are associated with temperatures betw 0.0° and —0.6°C.

Discussion

The origin of the deeper waters of Hudson Bay with temperatures than —1.0°C. and salinities greater than 33 per cent offers considera scope for conjecture. It is difficult to conceive of water of such charact istics being produced within the Bay, for it must be assumed that chilling took place in the upper layers. If such is the case, then at so

ie previous to the "freeze-up," the surface layer of lower salinities as served in the months of August and September must have been almost npletely removed from the bay. To deal with this problem thoroughly, need temperature and salinity data for the water column under the ter ice.

Again we may conjecture that this deep, cold, saline water is fed into Bay at the greater depths from Foxe Basin, and unfortunately we do have the data to fix the characteristics of the waters which are carried thward to Foxe Channel. It is not likely that salinities between 32 and 0/00 are characteristic of surface waters from the Polar Seas, and n if such waters were available at the greater depths of Foxe Channel l Basin, we would still have the problem of the origin of such waters.

We can, strictly on theoretical grounds, consider that with the advent the colder months the more saline surface waters of Hudson Strait are lled to their freezing point of approximately —1.7°C., in part by tidal xing on a large scale. This process of chilling produces a heavier type water than that which is formed in the Bay by the same chilling pro- ses. The dynamical tendency is then towards a seaward flow of the ter Bay waters, and an inward flow of the colder, more saline, and vier waters from Hudson Strait. As the chilling process progresses oughout the northern latitudes and the continental drainage is reduced a minimum, there is little augmentation of the surface layer in Hudson y. By freeze-up time the waters of Hudson Bay are quite uniform from to bottom, at a temperature just short of the freezing point and of a nity of approximately 32 to 33 0/00.

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Pen Surfaces and Odour Development in Trawler Fish Holds

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Various surfaces against which Atlantic groundfish were stowed aboard ship and in the laboratory were observed for their effect on the preservation of the catch. All fish taken from heavily contaminated wood surfaces carried vile-smelling, bilgy odours. No benefit was derived from washing these boards prior to stowage. Almost all fish in contact with painted and varnished wood and aluminum alloy surfaces, which were the best of the others tested, were free from bilgy and sour odours. Wood surfaces cannot be maintained intact in a fish hold, hence aluminum alloys or other corrosion-resistant, non-toxic metals such as Monel and nickel-steel are a good choice for all difficult-to-ice vertical surfaces of a fish pen. Metal screens which hold the fish off contaminated wood surfaces and at the same time retain crushed ice between the screens and these surfaces, provide an alternative construction method.

The purpose of this investigation was to learn the effect of various types of surfaces which may come in contact with the fish on the preservation of the catch; and to determine if hold linings impermeable to bacteria, e.g. metal surfaces, are necessary for the proper stowage of groundfish aboard Atlantic Coast trawlers.

The bacterial flora which cause deterioration in fish stowed at sea consist predominantly of psychrophilic organisms derived mainly from fish slime and feces. A

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large proportion of these organisms are facultative anaerobes. In the absence of air some species produce very strong fecal odours suggestive of bilge water, and fish developing this type of spoilage are referred to by the trade as "bilgy" fish *(4)*. Under conditions where atmospheric oxygen is available, these same species or other organisms produce various types of sour, turnipy, or putrid odours *(9, 10)*. Unpainted, porous, slime-soaked wood pen boards carry an extremely heavy bacterial load. When fish are pressed against them so that air cannot reach these areas, the slime becomes the breeding ground of large numbers of organisms, some species of which will produce fecal odours in the fish. On the other hand, well-preserved, close-textured materials do not carry heavy bacterial loads prior to the stowage of the fish. One would expect that spoilage, if it were to occur at all in fish stowed against such surfaces, would be caused for the most part by organisms carried in the slime and gills of the fish at the time of gutting, rather than in the boards. And while the presence or absence of air at the surfaces of these boards would control the type of spoilage which might develop in these perimeter-stowed fish, it would seem probable that a true anaerobic environment would be less likely to occur under these conditions than under those established when fish are pressed against slime-soaked surfaces.

EXPERIMENTAL PROCEDURES

Types and conditions of surfaces under test aboard ship. The surfaces tested on pen bottoms and in vertical positions are shown in Tables 1 and 2 respectively. Washing procedures adopted or other treatment of the boards prior to their use, are given in the footnotes to the tables.

The surfaces to be tested were placed on the bottoms and against the pen bulkheads, commonly called the "wings," of two fish pens in a trawler fishing out of Halifax. These surfaces, each of an area of about 7 square feet, were compared with the wood surfaces of the fish hold itself: the pen back walls which form the side wall of the boat, and the pen boards or division boards which measure about 200 square feet in area for each pen.

Stowage of fish aboard ship. For 5 fishing trips, no ice was placed between the cod or haddock being stowed and the surfaces under test, thus ensuring that the fish were stowed in contact with these surfaces. Crushed ice in the ratio by weight of about 1 part ice to 2 parts fish was used to surround those parts of the fish not in contact with the surfaces being investigated. This

ensured that the fish were chilled quickly and remained cool for the duration of the trip. Ice was mixed among all other fish stowed in the pens in the same ratio. The length of the fishing trip determined the length of time the fish were in contact with the surfaces. For the most part, the fish from the first day's catch were stowed in the test pens.

Examination of fish after landing. Upon discharge of the catch after each trip, representative samples were withdrawn from those fish in contact with the surfaces under test. Control fish, surrounded by ice, in the centre of the pen were also taken. All samples were examined for general appearance and odour upon being removed from the pens, and were re-examined soon after at the laboratory where they were filleted, skinned, and the skinned surfaces of the fillets examined for odour. The fillets were judged for marketability on the basis of appearance and odour. The fish were classified (a) *definitely bilgy* (b) *definitely sour* (c) *possessing mild off-odours* (possibly bilgy odours) and (d) *fish free of spoilage odours.* The author and another trained staff member carried out the examinations of samples from the 5 trips.

Stowage of fish in the laboratory. Experiments were also conducted in the laboratory since this permitted stowage against boards contaminated to different degrees, and removal of the fish from the boards after any desired period of stowage.

Two of three contaminated wood pen boards taken from a fish hold were brushed and washed in warm tap water and one board was then sterilized by exposure for 1 hour to steam at 15 p.s.i.g. The fish slime was left on the third board. The outside surfaces of 9 odour-free, gutted, unfilleted fish that had been 3 days on ice were given 3 brushings under running tap water, and the fish were then rinsed, both in the gut cavity and on the outside under running tap water, to ensure that the bacterial load carried on the fish would be uniformly minimal. Three fish were laid on each board and the boards were then placed on a bed of ice about 1 foot in depth within a painted spruce box, from which the melting ice water could escape. The fish were covered with crushed ice to a depth of about 1 foot. The box was stored at room temperature. One fish from each board was examined 2 and 7 days later, respectively.

To assess the effectiveness of the commercial procedure of brushing and washing the boards after each trip, the board of the previous experiment which had been washed but not steam sterilized was washed again, and tested as above. The process of stowing more fresh fish on the same board, which in each case was re-washed prior to being used, was repeated twice.

RESULTS

The results show a marked difference in keeping time of fish stowed against heavily contaminated wood surfaces from fish stowed against all other surfaces (Tables 1 and 2). All fish stowed against the former became bilgy. Fish in contact with the unpainted wood previously steam sterilized, showed no bilgy odours in the stowage period. Almost all fish in contact with

TABLE 1

Development of bilgy odours in fish stowed in contact with horizontal surfaces located in the bottom of fish pens [1, 2]

Type of surface	Species and class of fish	Elapsed time fish in stowage (days)	Definite bilgy odours on fish	Definite bilgy odours on fillets	Mild off-odours, possibly bilgy	Market-ability of fillets
Contaminated spruce boards that had been used previously in trawler holds	Scrod and market cod	7	yes	yes	.....	no
	Steak cod	7	yes	yes	.....	no
Freshly planed and unpainted spruce boards	Scrod and market cod	7	yes	yes	.....	no
	Steak cod (1)	10	no	no	no	yes
	(2)	7	yes	yes	.....	no
	Large haddock	7	yes	yes	.....	no
Freshly planed and painted spruce boards	Scrod and market cod	7	no	no	no	yes
	Steak cod	7	no	no	no	yes
		10	no	no	no	yes
	Large haddock	7	yes	yes	.....	no
Unpainted recently set Portland cement	Steak cod (1)	10	no	no	no	yes
	(2)	7	yes	yes	.....	no
	Large haddock	7	yes	yes	.....	no
Transparent plastic	Steak cod	7	no	no	no	yes
		10	no	no	no	yes
	Large haddock	7	yes	yes	.....	no
Aluminum alloy sheet	Steak cod	7	no	no	no	yes
		10	no	no	no	yes
	Large haddock	7	no	no	no	yes

[1] All data apply to samples which were taken from surfaces which had been brushed and washed with clean hot tap water prior to ship's departure for the fishing grounds.

[2] Where there were variations in the quality of samples drawn from similar surfaces, those samples given the higher rating are scored opposite the bracketed numeral one, i.e. (1), appearing in Column 2; and those given the lower rating are scored opposite the bracketed numeral two, i.e. (2).

Development of bilgy odours in fish stowed in contact with vertical surfaces located on the walls of fish pens [1,2,3]

Type of surface	Species and class of fish	Elapsed time fish in stowage (days)	Definite bilgy odours on fish	Definite bilgy odours on fillets	Mild off-odours, possibly bilgy	Marketability of fillets
Contaminated spruce boards that had been used previously in trawler holds	Scrod and market cod	7*	yes	yes	.....	no
		8*	yes	yes	.....	no
	Steak cod	4*	yes	yes	.....	no
		7*	yes	yes	.....	no
		10	yes	yes	.....	no
	Large haddock	7*	yes	yes	.....	no
		7	yes			
				yes	.....	no
	Small haddock	8	yes	yes	.....	no
Boards from same lot as above, but steam sterilized prior to test	Large haddock	7	no	no	no	yes
Freshly planed and painted spruce boards	Steak cod	10	no	no	no	yes
Freshly planed and varnished spruce boards	Steak cod	10	no	no	no	yes
Aluminum alloy sheet	Market cod	8	no	no	no	yes
	Steak cod	10	no	no	no	yes
	Large haddock (1)	7	no	no	no	yes
	(2)	7	no	no	yes	yes
	Small haddock	8	no	no	no	yes
Corrugated aluminum alloy pen boards (corrugations vertical)	Market cod	8	no	no	no	yes
	Large haddock (1)	7	no	no	no	yes
	(2)	7	no	no	yes	yes
	Small haddock (1)	8	no	no	no	yes
	(2)	8	no	no	yes	yes
Corrugated aluminum alloy pen boards (corrugations horizontal)	Market cod	8	no	no	no	yes
	Large haddock	7	no	no	yes	yes

[1] All data without the asterisks, with one exception, apply to samples which were taken from surfaces which had been washed with clean hot tap water prior to the ship's departure for the fishing grounds. The exception applies to the boards which were steam sterilized after being washed in the above mentioned way.

[2] All data accompanying the asterisks apply to samples taken from surfaces which had been washed with harbour water (hot) prior to the ship's departure.

[3] Where there were variations in the quality of samples drawn from similar surfaces, those samples given the higher rating are scored opposite the bracketed numeral one, i.e. (1) appearing in column 2; and those given the lower rating are scored opposite the bracketed numeral two, i.e. (2).

painted and varnished wood and aluminum surfaces, which were the best of the other surfaces tested, were free from bilgy odours.

There was no benefit derived from our method of washing worn wood boards between trips. The same washing procedure proved effective in almost all cases when used with aluminum alloy and painted wood surfaces.

Bilginess appeared to be equally strong in fish stowed against vertically disposed worn wood boards at the top and at the bottom of the wings and in those stowed against horizontally disposed boards of similar type, size, and shape located at the bottom of the pen where the fish are under considerable pressure.

All well-iced fish not in contact with pen boundaries were free from bilgy and sour odours.

Sour odours were found in a few fish in contact with all the surfaces tested. These odours were detected only when those of the bilgy type were absent or slight.

The results of the laboratory experiment on fish stowed against wood boards were: (a) bilgy odours were observed in fish lying against the washed board and the slimy board, 2 days after the fish had been stowed; (b) examination of fillets cut from these fish showed that the vilest odours were associated with fish that had been in contact with the washed board; (c) no bilgy odours had developed in fish against the sterile board up to a period of 7 days, at which time the test was terminated; (d) deslimed fish which were later stowed against a previously contaminated and then washed board, developed bilgy odours during each of 3 successive tests after being in contact with the board for 2 days only.

DISCUSSION

In the Nova Scotian and Newfoundland Banks fishery, spoilage of the bilgy type may be expected in fish stowed in contact with washed, rough-surfaced, slime-soaked wood boards as early as 4 days after stowage, while similar spoilage may be found infrequently in fish in stowage for 7 and 8 days and more against washed, well-painted wood boards and aluminum alloy surfaces. Sourness may occur in fish in contact with well preserved surfaces but this should not be a serious factor aboard a trawler where a reasonable amount of care is taken with the icing.

The pronounced difference in the keeping time of fish in contact with worn wood in contrast to metal, suggests that wood holds, despite low first cost, may be very expensive. Metals, for use in all difficult-to-ice sections of the fish pen, e.g. all vertical walls, should be a good investment. Well-painted wood boards may give equally good results at first, but it is impossible to keep them in first-class condition when they are subject to heavy

wear and tear. Ultimately, many of these boards carry heavy bacterial loads.

Two trawlers with holds properly insulated, properly refrigerated, and completely lined with aluminum are in operation out of fishing ports on the Canadian Atlantic coast *(7)*. Although the data which have been collected are not adequate to determine precisely the difference in keeping time between fish stowed in this type of hold and in the conventional hold, the available information is in general agreement with the results obtained in this work. We wish to make reference also to other publications describing the use in fish holds of aluminum alloys *(5, 8)*, Monel *(1)*, and nickel-clad steel *(2, 3)*.

Another solution to the problem encountered in the stowage of fish against wood wings may be the use of screens. Preliminary work has shown that wire screens of 1½ inch mesh, held off the side walls at a distance of about 1 inch, permit the ice to fill the intervening space and hold the fish away from the walls *(6)*. This device was effective in eliminating the occurrence of bilgy fish.

SUMMARY

Of the materials and surfaces studied, rough, unpainted wood boards were shown to be a very serious source of contamination of fish at all levels in the pen. These surfaces could not be effectively washed.

Painted and varnished wood surfaces were impermeable to bacteria in most cases. However, when used commercially, many of these surfaces ultimately become broken and eroded.

Aluminum, or probably any other corrosion-resistant, non-toxic metal, gives a satisfactory surface. Such surfaces provide a reasonable guarantee against bilgy and sour odours, provided the catch is well iced.

If the fish are not protected by the use of all-metal pens, they should be kept away from slime-bearing pen surfaces with ice. Screens along the pen sides are useful aids.

The vertical walls and boards of the pen are the most difficult to ice properly. If only part of the pen can be of metal, the walls should be given priority.

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Ices Containing Chlorotetracycline in Experimental Fish Preservation

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Methods of preparing flake-type and block ice containing added chlorotetracycline (CTC) are described. Relatively uniform distribution of CTC throughout ice blocks prepared by conventional slow-freezing procedures is attained by addition of carrageen (CG) preparations or carboxymethylcellulose (CMC) to the water used in its manufacture. Heating aqueous suspensions of CG in order to effect its solution may be avoided, at least with certain types, if the dry, finely powdered material is mixed with propylene glycol prior to mixing it with cold water. The ability of CG to effect dispersion of CTC throughout ice blocks is normally improved by the addition of both KCl and $CaCl_2$. Improved distribution of certain food colors, acridine dyes and aniline dyes in ice blocks is effected by addition of CMC or CG.

Bacterial spoilage of eviscerated fish is normally markedly delayed by icing them with flake or crushed block ice containing about 1 p.p.m. of CTC, rather than with ordinary ice, or by holding eviscerated or non-eviscerated fish at —2° C. in sea water containing from 1 to 4 p.p.m. of CTC. Experiments carried out on fishing boats and ashore show that failure to apply CTC ice promptly after fish are caught, a comparatively short period during which the fish are in contact with the ice, and poor icing procedures, all interfere seriously with the effectiveness of the ice.

Previous reports have indicated the outstanding effects obtained with chlorotetracycline (CTC) in retarding bacterial spoilage of fish *(4, 11, 12)*. Recently

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these findings have been confirmed for fish and shrimp by Farber *(2)* and for shrimp by Idyll *(5)*. With shrimp, as with crab meat which also has a rather alkaline reaction, the concentration of CTC required for effective preservation is considerably higher than that normally found satisfactory for fish *(11)*. The work to be described was initiated in order to ascertain the value of CTC as a fresh fish preservative when applied under normal commercial conditions. It has involved the preparation of flake-type of ice containing the antibiotic, and has included the design of a method by which it can be distributed uniformly throughout blocks of ice prepared by customary slow-freezing procedures. These ices have been used to ice fish on commercial fishing vessels. Further tests concerning the effect of inclusion of CTC in refrigerated sea water on keeping quality of fish transported in this medium *(12)* have also been made.

PREPARATION OF FLAKE-TYPE ICE

CTC was incorporated in the water used for preparation of ice made in a small "North Star" type of machine by the following procedure. Since the water used was hard (pH about 7.2), and the stock solution of the antibiotic was, for convenience, prepared only once daily, it was found necessary to add citric acid (200 p.p.m. final concentration) to adjust the pH of the 60 p.p.m. CTC solution to 3.5. Microbiological assays carried out by the "pad plate" method *(1)* showed that the antibiotic was relatively stable in solution at this pH value. In the unacidified water 70% of the antibacterial activity was destroyed in 24 hours at 20° C., and 100% in 24 hours at 25° C.

The stock antibiotic solution was prepared in a raised galvanized 300-lb. ice can which was coated inside with a corrosion-resistant and water-resistant rubber base paint. The citric acid and CTC were mixed conveniently by rapid introduction of the water by means of a perforated filling pipe situated at the base of the tank. A plastic hose, the open end of which was covered by a fine mesh brass cloth screen, permitted liquid to flow by gravity from the bottom of this tank to an ordinary porcelain toilet tank via a simple ball-float valve. A constant "head" of liquid was thus maintained. The rate of flow of this solution from the bottom of the porcelain tank to the ice-making machine sump was adjusted to about 200 lb. per day by means of a needle valve which was carefully screened with brass cloth. The flow rate could also be adjusted by a slight raising or lowering of the porcelain tank.

Microbiological assays of ice prepared as above were made at intervals during the fishing season and have yielded the following results (p.p.m. CTC): 0.94, 1.4, 0.9, 1.3, 1.1, 0.86, 1.3, 1.5, 0.6, 0.7, 0.96, 1.3, 1.1. The average, 1.07, agrees fairly well with the

expected value which is 1.25. Partial or complete melting of ice samples which occasionally occurred during their rather long shipment in ice to the laboratory may account for some of the rather low values.

PREPARATION OF BLOCK ICE

A brief report describing preliminary experiments concerned with devising a method of distributing CTC throughout ice blocks which are slowly frozen has been published *(3)*. In ordinary aqueous solution crystalloids, unless present in eutectic concentration, and suspended solids tend to freeze into a central "core" *(9)* which is normally located near the bottom of ice blocks. Laboratory experiments were carried out by freezing 4-liter quantities of water in 9½ x 7 x 4 inch cans in still air at about —25° C. Three-hundred-pound blocks of ice were prepared under normal commercial conditions. The following "distributing agents" were employed: CMC (Hercules carboxymethylcellulose 70, high viscosity), carrageen (CG) 1 ("Seakem" type 5), CG 2 ("Seakem" type 9P), CG 3 ("Seakem" type 14), CG 4 ("Seakem" type 402), CG 5 ("Kraystay S"), CG 6 ("Kraystay T"), an alginate ("Dricoid"), a water-ice stabilizer ("Viscold") and "Difco" gelatin. Experiments with CG preparations 2, 3 and 4 indicated an effectiveness similar to CG 1 except in their response to added salts. CG 1 and CG 6 were identical in distribution effect upon addition of salts, CG 5 being somewhat less effective. In the figures most of the data are for CG 1 since the results obtained with it were representative of those found for other CG preparations.

In some experiments the CG preparations were brought into solution by heating 1% aqueous suspensions to 90° C. The following method proved more convenient for CG preparations 1 and 6: The dry powdered CG (100-mesh or finer) was mixed with twice its weight of propylene glycol, and was then made into a 5% paste with cold water. To this paste 0.5% of a surface active agent (e.g. "Sterox") was added to facilitate distribution. The resulting paste was added to the ice cans, preferably by means of a gear pump, and was then mixed with a strong jet of cold water, the CTC and inorganic salts being added during the filling procedure. In this procedure dry CG preparations which have no added potassium or calcium salt should be used, since the propylene glycol-aqueous gels cannot be dispersed properly in water if the salts are present. In most instances it is advisable to add both potassium and calcium salts to the CG preparations, for it has been found that these salts cause improved distribution of CTC. Certain CG preparations (e.g. CG 6) contain added KCl. CMC and alginate preparations were made into 1% solutions with cold water. Gelatin was dissolved in warm water.

Sampling. In initial experiments the small ice blocks were sampled by cutting them into 6 approximately equal portions with a band-saw (Figure 1). Later, sampling of these was changed to conform with that used for the large blocks *(vide infra)*. Slices ¾-inch thick were taken from the 4 large surfaces

(sample 1), and the remaining core was then sawn into three approximately equal segments; top, centre and bottom (samples 2, 3 and 4 respectively; Figure 3). Three-hundred-pound blocks were sampled by chipping ice to a depth of about 2 inches from representative localities on the four large surfaces. The blocks were then cut in half (longitudinally), and three further samples secured by chipping ice to a depth of about 2 inches from the freshly exposed surfaces of the top, centre and bottom pieces, keeping within a distance of 2 inches from each edge. In this last method sample 1 is by far the most crucial since it represents about 50% of the total volume of the blocks.

EFFECT OF VARIOUS "DISPERSING" AGENTS ON DISTRIBUTION OF CTC IN ICE BLOCKS

For economic reasons the lowest concentration of "dispersing" agent capable of causing a relatively uniform distribution of CTC (1 p.p.m.) in ice was sought. In initial tests with small blocks 0.1% CG 1 plus KCl (.01%) caused practically ideal distribution of CTC, while 0.02% was very effective. On the other hand the alginate preparations and gelatin were practically ineffective (Figure 1). Early tests with an old sample of CMC indicated that this was less effective than the carrageens *(3),* but further tests with the new sample have indicated that this substance has excellent distributing properties *(vide infra).* In further experiments the effect of several CG samples, with and without added KCl and $CaCl_2$ (each salt added in amount equivalent to 10% of dry gel weight), on distribution of CTC in commercial ice blocks was investigated. The propylene glycol method of introducing the CG was also studied. The results of several typical experiments are shown in Figure 2. Without added KCl 0.02% of CG 1 caused a somewhat more uniform distribution of CTC than did CG 5. With added KCl (0.002%) both types were about equally effective in causing even distribution. The propylene glycol method of adding CG was quite effective. In the presence of KCl plus $CaCl_2$ 0.01% of CG was slightly more effective than 0.005%, but from a practical standpoint the lower level should prove adequate for ice which is subsequently crushed and mixed. In the absence of the added salts distribution was less uniform. In another experiment using small ice blocks it was found that 0.005% of CMC effected a uniformity of distribution of CTC which was identical with that occasioned by 0.005% of CG 1 plus KCl and $CaCl_2$. In the case of CG preparations 1, 5 and 6 addition of salts was necessary for maximum effectiveness, while the activity of CMC was not influenced by the addition of salts. With CG preparations 2, 3 and 4 addition of salts resulted in poorer distribution (Figure 3). These 3 types were not amenable to the propylene glycol method probably as a result of a higher natural concentration of inorganic salts.

DISTRIBUTION OF SUBSTANCES OTHER THAN CTC

The general applicability of this method of distributing solutes throughout a large mass of ice which is frozen slowly

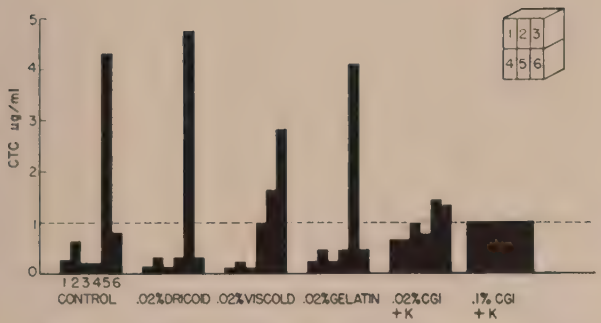

Figure 1. Effect of various agents on distribution of CTC in small ice blocks.

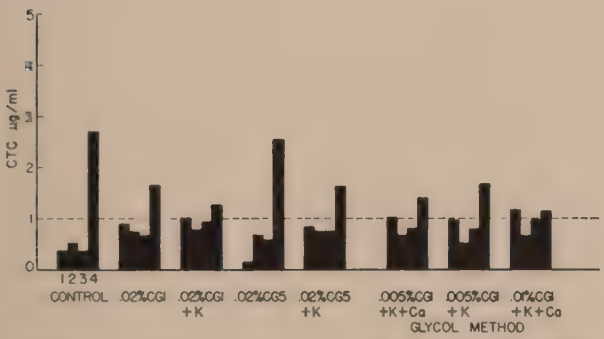

Figure 2. Effect of Cacl, KCl, and the propylene glycol method on the distribution of CTC in commercial ice blocks.

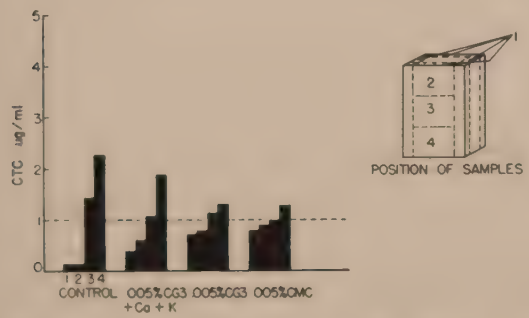

Figure 3. Effect of CMC and of salts added to certain carrageens on the distribution of CTC in small ice blocks.

was investigated. With sodium nitrite (0.1%), which has been used quite extensively as an inhibitor of spoilage of fresh fish *(10)*, 0.1% CG 1 failed to improve distribution. The distribution of certain common biological stains (Safranin Y, methylene blue and fluorescein, and the bacteriostatic acridine dyes "Trypaflavin" and "Rivanol") was definitely improved with 0.05% of CG as compared with that normally occurring in absence of a distributing agent. On the other hand there was a strong tendency for a precipitate containing some of the dye to accumulate at the bottom of the ice blocks. This layer is probably due to the precipitation of positively charged dye molecules with negatively charged CG particles *(6)*.

A number of tests were made with several recognized food colors using 0.05% of CMC as dispersing agent, since in several exploratory experiments this substance had given better results than the CG preparations. The results, using small blocks and the same sampling technique as shown in Figure 2 are given in Table 1. They show that the CMC effected a resonably even distribution of these colors which did not occur in ordinary aqueous solutions.

In conclusion, it is important to note that the final choice of a gel system for facilitating distribution of a given solute throughout an ice mass will depend on a number of factors as yet incompletely understood. These may include physical adsorption of the molecules of the solute upon the gel particles or an actual retardation of the rate of flow of the solute through the gel. The final selection of the best combination would have to be evolved for each solute. For CTC in concentrations of a few p.p.m., 0.005% of a suitable type CG, with added KCl and $CaCl_2$ incorporated by the propylene glycol method would appear economical. CMC has the advantage that it does *not* require added salts and is considerably cheaper than the CG preparations, but due to its viscosity it has to be added in a relatively low concentration (e.g. about 1%) to the water used in making ice. This means that 675 ml. of 1% CMC solution is required for a 300-lb. ice block, while only 135 ml. of propylene glycol—5% CG gel would be required.

PRESERVATION OF TROLL-CAUGHT COHO SALMON WITH FLAKE-TYPE ICE CONTAINING CTC

The fish were caught off the west coast of Vancouver Island and were dressed and the kidneys removed in the usual manner, the visceral cavities being washed with sea water. Some fish were iced with ordinary crushed ice and others with flake ice prepared as previously described and containing approximately 1 p.p.m. of CTC. A number of fish were marked at certain intervals during fishing so that their *post-mortem* age was known at the time of sampling. The fish were weighed at the receiving plant after de-icing, and they were then iced again with the respective ices for shipment by truck to Vancouver. Several fish were selected at random and centre steaks about 1 inch thick cut from each under clean conditions. In most instances the steaks, wrapped in cellophane, were given an addi-

TABLE 1

Distribution of food colors in small ice blocks[1]

Color	Conc. (γ/ml.) used	λ (mμ)	Gel samples				Controls			
			1	2	3	4	1	2	3	4
			Optical density				Optical density			
Egg yellow	5.0	434	.131	.145	.113	.105	.010	.030	.336	.357
FDC orange No. 1	2.5	478	.253	.257	.175	.175	.010	.024	.792	.520
FDC red No. 1	2.5	502	.130	.140	.092	.098	.011	.016	.205	.325
FDC blue No. 1	2.5	635	.400	.350	.315	.300	.017	.038	.462	1.15

[1] Hercules CMC 70 high and National Aniline food colors supplied by Harrisons and Crosfield (Canada) Ltd. Sampling method was the same as for small CTC-containing ice blocks. The optical density of melted ice was determined with a Beckman DU spectrophotometer.

tional aging at 0, 4 or 10° C., since this procedure is considered to give valuable information regarding the potential keeping quality of the fish *(7)*. The results, given in detail in Table 2,

TABLE 2

Comparative keeping quality of eviscerated coho salmon in ordinary ice and in flake ice containing approximately 1 p.p.m. CTC

Post-mortem age at time of sampling (days)	Aging procedure	Bacteria × 10^6 per g.	
		Ordinary ice	Chlorotetracycline ice
3	24 hr. at 10° C.	2.0	0
5		3.8	0
8		3.7	0
3-5	24 hr. at 10° C.	2.2	0
7		8.7	0
9		17	0
12	20 hr. at 0° C.	50	0
9	4 days at 4° C.	56	0
12		110	0
7	2 days at 10° C.	20	0
9		37	0
12		55	0
12	24 hr. at 10° C.	93	0.4
17	None	394	3.3

show that the CTC-containing ice caused a spectacular decrease in the rate of bacterial spoilage of the fish. In most instances a direct count of $<0.27 \times 10^6$ bacteria per g. was found with the CTC-iced fish. With a number of fish samples which had an initial count of 0 based on 10 microscopic fields, only about 0.27×10^3 bacteria per g. were found when 200 fields were counted. In all instances at a stage where the actual fish had become stale organoleptically, those stored in CTC-containing ice were still not appreciably spoiled.

The effect of crushed block ice prepared by the CG method, and which contained approximately 1 p.p.m. of CTC, on keeping quality of salmon under commercial conditions on salmon packers and under laboratory conditions was investigated (Table 3). In the first experiment troll-caught coho salmon, which had apparently been dressed on the fishing boats and iced only on arrival at the fish camp, were studied. These fish had an uncertain history, but probably had a *post-morten* age of 5-8 days when they were collected. They were iced with the experimental ices in the collecting packer. Usually this icing procedure used on fish packers is not very thorough since the fish are rarely on board for long. In this experiment they were about 1½ days on the packer before they were landed. A number of fish were sampled at random, and the centre steaks were stored at 4° C. for 4 days prior to making the bacterial counts. The results

show that under these conditions, which permitted a relatively brief exposure to the CTC ice, only a slight and practically insignificant improvement in keeping quality was apparent.

In a further experiment round (non-eviscerated) seine-caught chum salmon of good quality were iced on a fish packer within 12 hours of capture. The fish were stored on the boat about 1½ days before they were landed. Three fish from each ice were eviscerated, repacked in their respective ices and stored in them for a further 10 days. Samples were taken from other fish and given accelerated aging for 4 days at 10° C. The results (Table 3) show that there was only a slight difference in keeping quality in the accelerated aging test, but that the fish stored for 12 days in the CTC ice were in much better condition than those stored in ordinary ice.

TABLE 3

Comparative keeping quality of salmon stored in ordinary ice and in crushed block ice containing approximately 1 p.p.m. CTC

	Bacteria × 10^6 per g.[1]	
	Ordinary ice	CTC ice
Experiment 1, Coho salmon	423, 362, 206, 161 337, 317, 270, 298: $\bar{x}$ 298	206, 125, 189, 158 114, 156, 270: $\bar{x}$ 174
Experiment 2, Chum salmon	78, 64, 60, 54: $\bar{x}$ 64 74.5 (10 days in ice)	17, 19, 25, 22: $\bar{x}$ 20.7 1.9 (10 days in CTC ice)
Experiment 3, Sockeye salmon		
9 days	19	0
14 days	242	2.1

[1] Each figure is the average for two fish.

A third test was made using round sockeye salmon in very good condition which had been collected shortly after capture and carried in ordinary ice for about one day on a fish packer. Several fish were selected at random, eviscerated, and the visceral cavities washed superficially with water. Four fish were iced in ordinary ice and four in crushed block ice containing about 1 p.p.m. of CTC. Two fish from each ice were examined after 9 days and 14 days in ice. The results (Table 3) show the greater effectiveness of the CTC ice than ordinary ice under these conditions.

The above three experiments reveal the limitations which apply to use of CTC ice in practice. Thus it is apparent that (a) a long interval *post mortem* before the antitbiotic ice is applied, (b) too short an application, or (c) poor icing procedures all seriously interfere with its effectiveness.

CTC IN REFRIGERATED SEA WATER

During the past few years renewed interest has been evidenced in the possibility of holding and transporting fish in mechanically refrigerated sea water at about —1

to —1.5° C., and the results of several previous experiments concerning the effectiveness of added CTC in retarding bacterial degradation of fish transported in this medium have been published *(12)*. To accumulate further and more extensive information regarding the value of this method several trials were made on a small fishing boat equipped with two refrigerated sea-water tanks, and which could ice fish simultaneously. Four separate experiments were conducted on this boat and the results are given in Tables 4 and 5. In the first experiment salmon were eviscerated at sea and treated in four ways as follows: (a) iced with ordinary crushed ice;

TABLE 4

Comparative keeping quality of salmon in refrigerated seawater and in ice with and without added CTC

	Bacteria × 10^6 per g.	
	Controls	Plus CTC
Experiment 1		
Coho (blueback) salmon in sea water (eviscerated)	6.7	0
	16.7	0
	19.5	0
	2.8	0
White spring salmon in sea water (eviscerated)	1.0	0
Coho (blueback) salmon in ice (eviscerated)	5.6	0
	3.6	0
	4.5	0.8
Experiment 2[1]		
Chum salmon in sea water (eviscerated)	16	0
	26	0
	28	0.27
	31	0.83
	44	
	45	
Chum salmon in sea water (not eviscerated)	11	0.27
	13	0.43
Experiment 3[1]		
Coho salmon in sea water (eviscerated)	38.0	0.5
	51	5.8
	43	6.1
Coho salmon in sea water (not eviscerated)	17	1.1
	27	1.4
	30	1.6
Experiment 4[1]		
Grey cod in sea water (eviscerated)	32	0.27
	43	0.41
	53	2.5
Lemon flounder in sea water (not eviscerated)	41	0
	51	0
	62	0

[1] Each figure is the average for two fish.

TABLE 5

Viable bacteria and CTC in seawater in experiments 1-4

Experiment	CTC added (γ/ml.)	Seawater alone	Seawater + CTC	
		Bacteria per ml. (× 10^6)	Bacteria per ml. (× 10^6)	CTC (γ/ml.)
1	4	....	....	3.8
2	4	1.2	0.01	2.1
3	2	36	2.1	1.6
4	1	1.5	0.17	0.8

(b) iced with crushed block ice containing approximately 1 p.p.m. of CTC; (c) held in refrigerated sea water at —1.5° C. and (d) held in refrigerated sea water containing 1 p.p.m. of CTC (calculated on the total volume of fish plus sea water). The fish were stored 8 days on the boat and, after landing, were sampled as usual and the samples aged 1 day at 10° C. The results (Table 4) showed that the treatments could be given the following order of preference when based on bacterial counts: refrigerated sea water plus CTC, ice plus CTC, ordinary ice and refrigerated sea water. The results with the refrigerated sea water alone were somewhat unexpected, since the fish in this medium were superior in appearance and firmness on arrival to those stored in ordinary ice. However, the sea water, which was not changed for 8 days, was probably heavily contaminated with bacteria which grew on the fish samples during the accelerated storage period. This difficulty was also experienced in experiment 3 *(vide infra)*.

In the second experiment both eviscerated and round non-eviscerated chum salmon were stored 9 days in refrigerated sea water with and without added CTC, the fish eviscerated where necessary, and samples aged for 2 days at 4° C. The results are of special interest for they show that the CTC greatly improved the keeping quality of both eviscerated fish and fish which were not eviscerated for 9 days. In a further and rather similar test coho salmon were kept in both eviscerated and round condition in refrigerated sea water for 8 days. Samples were then taken and stored for 1 day at 10° C. The results again showed that the presence of CTC in the sea water greatly improved keeping quality of both round and eviscerated fish. In both experiments 2 and 3 the bacterial counts obtained with the round fish were,

indeed, somewhat lower than with eviscerated fish. Experiment 4 showed that addition of CTC to refrigerated sea water caused a marked delay in the rate of bacterial spoilage of eviscerated gray cod and non-eviscerated lemon flounders.

In the above experiments the number of bacteria present in certain of the sea-water samples was determined by viable plate count using the following medium: "Difco" nutrient broth (0.8%), yeast extract (0.5%) of sea water (25%) and agar (1.5%). An incubation period of 7 days at 25° C. was used. The CTC content of the sea water was also determined by microbiological assay. The results (Table 5) show that there were considerably fewer viable bacteria in the sea water containing CTC, and that the antibiotic was relatively stable for days under the experimental conditions. In experiment 3 the sea water had a relatively high bacterial content and an unpleasant odor. The fish, however, were not seriously spoiled, and in canning gave a product which on inspection was conceded to be satisfactory. The amount of CTC added was always based on the calculated volume of a *full* tank (sea water plus fish), and since the actual amount of fish varied considerably in each experiment, the actual CTC content of the sea water alone at the commencement of the experiments could not be determined conveniently. In transporting fish on boats by this method it is essential to fill the tanks to avoid serious "splashing."

The use of CTC should be of great value in transporting fish in tanks containing refrigerated sea water, particularly since it can be used to advantage with fish which are not eviscerated. The tanks, pipes, etc. should be thoroughly cleaned between trips to prevent contamination of fresh sea water, and more particularly to avoid any possibility of creating a "CTC resistant" bacterial flora. In the present work the rather small tanks used have been adequately cleaned by simply washing them with clean water and then filling them with water containing 0.01% of the non-corrosive cationic detergent germicide alkyl dimethyl benzyl ammonium chloride. In former experiments this compound was found to exert a strong bactericidal action toward mixed marine bacteria *(8)*.

Acknowledgments

We are indebted to Mr. John Haining for designing the equipment for continuous addition of CTC solutions in the manufacture of flake ice. Our thanks are due to the B. C. Packers Ltd., The Canadian Fishing Co., and Mr. Martin of the Vancouver Ice Co., for providing facilities for the commercial experiments. The chlorotetracycline (Aureomycin hydrochloride) used was generously donated by Lederle Laboratories Division of the American Cyanamid Co., the CG samples by the Seaplant Chemical Corporation and Kraft Foods Ltd., and the carboxymethylcellulose and National food colors by Harrisons and Crosfield (Canada) Ltd.

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CORYNOSOMA HADWENI VAN CLEAVE A PROBABLE SYNONYM OF *C. WEGENERI* HEINZE (ACANTHOCEPHALA)

Van Cleave (1953a, J. Parasit. **39:** 1–13; 1953b, Illinois Biol. Monogr. **23:** 1–179) described as a new acanthocephalan species, *Corynosoma hadweni*, from seals caught mainly in the vicinity of Alaska. In his monograph on the ACANTHOCEPHALA of North American mammals, Van Cleave (1953b) listed the following definitive hosts of *C. hadweni*: *Halichoerus grypus* from Unalaska, Alaska; *Phoca hispida* from Point Barrow and Kotzebue, Alaska, and from Baffin Island, Eastern Canadian Arctic; *Erignathus barbatus* from Point Barrow, Alaska; *Phoca* sp. and unidentified seals from Kotzebue, Unalakeet, and St. Lawrence Island, Alaska. He also identified as *C. hadweni*, larvae (cystacanths) from visceral cysts in a fish (*Osmerus mordax*) collected from the State of Maine, thus indicating that the species subsequently would be found in seals of the western North Atlantic.

TABLE 1. *Comparison of* C. hadweni *and* C. wegeneri.

All measurements in millimeters. Measurements and numbers of hooks deduced from illustrations are placed in parentheses.

	C. wegeneri	*C. hadweni*
Total body length male and female	4.5	6–8.25
Max. diam. fore-trunk		
male	1.02	1.43
female	1.02	1.43–2.50
Diam. hind-trunk	0.25–0.35	1/5–2/5 fore-trunk
Trunk spines	Ventrally extend posteriorly about ⅓ hind-trunk	Ventrally usually extend not much beyond swollen fore-trunk
	(0.024–0.035 by 0.007–0.008)	0.026–0.046 by 0.008–0.014
Genital spines, male	Present—no measurements	0.024–0.035 by 0.010
Proboscis—		
Length	0.84	0.84–0.93
Max. diam.	0.275	0.30–0.37
Diam. anteriorly	0.20	0.23
Probosics hooks—		
No. long rows	15 or 16	16
No. hooks in each row	10 or 11	10 or 11 (9–11)
No. simple hooks in each row	4 (4 or 5)	5 or 6 (3–5)
No. hooks with recurved roots in each row	6 (6 or 7)	(5–7)
Size of proboscis hooks—		
Near distal end	(0.045–0.070 by 0.006–0.014)	0.079–0.104 by 0.004–0.016
On swollen region	(0.074–0.090 by 0.024–0.035)	0.105–0.150 by 0.026–0.041
Basal hooks	(0.033–0.051 by 0.004–0.010)	0.046–0.061 by 0.005–0.011
Embryos	0.108 by 0.030	0.093–0.115 by 0.020–0.035

Kruidenier (1954, J. Parasit. **40:** 363–364) pointed out that *H. grypus* does not occur in Alaskan waters and hence Van Cleave's records of ACANTHOCEPHALA in that host in Alaska are incorrect. He further suggested that the seals referred to as *H. grypus* were almost certainly *Phoca vitulina richardi*.

In his papers, Van Cleave discussed the species of *Corynosoma* found in PINNIPEDIA of the Northern Hemisphere, but apparently overlooked *Corynosoma wegeneri* Heinze (Heinze, K. 1934, Wissensch. Ergebn. Deutschen Grönland—Expedition Alfred Wegener, 1929 und 1930 **31 6:** 185–189, Leipzig) from *Phoca hispida* of Greenland. In comparing the descriptions of *C. hadweni* and *C. wegeneri* there is little, if anything, that distinguishes the two species. The description of *C. wegeneri* lacks certain details, particularly measurements of proboscis hooks and body spines. Nevertheless it still appears that *C. hadweni* and *C. wegeneri* are conspecific, with ***C. hadweni* falling as a synonym of *C. wegeneri*.**

In the accompanying table a comparison is made between *C. wegeneri* and *C. hadweni*. Measurements of proboscis hooks and body spines of Heinze's specimens had to be calculated from his illustrations. These measurements are, generally, smaller than the corresponding ones given by Van Cleave for *C. hadweni*. However, measurements based on calculations from illustrations, particularly of small structures, cannot be relied upon for accuracy. Furthermore, Heinze's illustration of the proboscis, according to the accompanying scale, indicates that this

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structure is only 0.7 mm. in length by about 0.25 mm. in maximum width. In the text Heinze gives the length and maximum width of the proboscis as 0.84 mm. and 0.275 mm. respectively. On the presumption that the illustration is of the same specimen to which measurements in the text apply, it appears that the figure of the proboscis and hooks was drawn to a smaller scale than indicated, and consequently the hook sizes calculated from the illustration are considerably less than their actual sizes. Further discrepancies are evident between the text and illustrations of the number of proboscis hooks in both *C. hadweni* and *C. wegeneri*. These are indicated in the table.—Leo Margolis—*Pacific Biological Station, Nanaimo, B. C., Canada.*

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[Contribution from The Pacific Fisheries Experimental Station]

Marine Sterols. I. Isolation of 24-Methylenecholesterol from Molluscs

By D. R. Idler and U. H. M. Fagerlund

Received October 8, 1954

A new sterol, 24-methylenecholesterol, has been isolated by a chromatographic separation of the azoyl esters prepared from the sterols of the oyster (*Ostrea gigas*) and the clam (*Saxidomus giganteus*). Oyster and clam sterols contain 36 and 53% respectively, of this sterol.

It has long been recognized that oysters contain sterols other than cholesterol.[1,2] Ostreasterol has been isolated from several molluscs including the oyster, *Ostrea virginica*.[2] There have been several structures proposed for this sterol but the most recent evidence indicates that it is identical with chalinasterol($\Delta^{5,22(23)}$-campestadiene-3β-ol).[2-4] However, the evidence appears to be based solely on a resemblance of physical properties, a frequently unreliable criterion when applied to sterols. Ostreasterol was first isolated as the most insoluble steryl acetate from *Ostrea virginica* and later it was purified further *via* the tetrabromide.[2,3]

In the present investigation 24-methylenecholesterol was isolated by chromatography of the steryl azoates prepared from the sterols of the oyster (*Ostrea gigas*) and the butter-clam (*Saxidomus giganteus*), on silicic acid. This sterol does not have the same properties as ostreasterol, for when the mixed acetates from *Ostrea gigas* were recrystallized repeatedly, the most insoluble acetate was still a mixture composed of 29% 24-methylenecholesterol and 71% of chromatographic zone 3. Thus judging from the original composition, zone 3 and not zone 2 (24-methylenecholesterol) forms the more insoluble acetate. Zone 3 has been shown to contain two double bonds by hydrogenation and perbenzoic acid titration. Thus, since there are at least two disunsaturated oyster sterols, purification *via* the tetrabromides does not appear to be nearly so desirable as the present chromatographic separation. The infrared spectra clearly show that neither zone 2 nor zone 3 sterol contains a *trans*-22,-

(1) M. Tsujimoto and H. Koyanagi, *J. Soc. Chem. Ind. (Japan)*, **37**, 436B (1934).
(2) W. Bergmann, *J. Biol. Chem.*, **104**, 317 (1934).
(3) W. Bergmann, *ibid.*, **104**, 553 (1934).
(4) W. Bergmann and E. M. Low, *J. Org. Chem.*, **12**, 67 (1947).

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23-bond (as does chalinasterol = ostreasterol) because of the absence of a strong band at 10.3 μ (970 cm.$^{-1}$).[5] The absence of either a *cis*- or *trans*-22,-23-bond is demonstrated further by the failure of either zone to yield methylisopropylacetaldehyde upon ozonolysis under conditions where good yields were obtained from ergosterol.

The sterol from chromatographic zone 2 has the same parent nucleus as campesterol. Zone 2 was reduced to the stanol with Adams catalyst in glacial acetic acid and the optical rotations of the stanol and derivatives were compared to those of campestanol (Table I). The saponification equivalent of zone 2 acetate furnishes additional evidence for the C_{28} skeleton.

TABLE I

PROPERTIES OF ZONE 2 STANOL

	Zone 2		Campestanol	
	M.p., °C.	$[\alpha]^{22}D$	M.p., °C.	$[\alpha]^{22}D$
Acetate	144	+18.2°	144	+18.3°
m-Dinitro-bz.	199	+22.4	199	+22
Stanol	145	+32.6	146	+32
Sapn. equiv.	Calcd. 441		Found 445	

The infrared spectra of zone 2 and the optical rotational differences of its derivatives definitely establish the presence of a double bond at the 5-position. This is confirmed by the reaction rate of the sterol when treated with the modified Liebermann–Burchard reagent.[6,7]

The isolation of formaldehyde in good yield (50%) by the ozonolysis of zone 2 establishes that the additional double bond must be at the 20,21-, 24,28- or 25,26-position. The solid film infrared spectra of zone 2 sterol differs from that of campesterol and other Δ^5-sterols by the presence of a strong band at 890 cm.$^{-1}$ and a band of medium strength at 1640 cm.$^{-1}$. This evidence confirms the structure CH_2=CRR.[1] A shoulder at 1362 cm.$^{-1}$ indicates the presence of the *gem*-dimethyl group at C_{25} and the band at 1330 cm.$^{-1}$ is quite possibly due to the CH group at C_{25}.[8] Further, the decomposed ozonide from a 25(26)-bond would yield a methyl ketone and the product of such treatment gave no iodoform reaction. Thus the absence of a 25,26-bond is indicated.

Conclusive proof that the new sterol is 24-methylenecholesterol was obtained by the isolation of 24-ketocholesterol from the ozonolysis products. This sterol has been synthesized[9] previously and also isolated from the products of the ozonolysis of fucosterol ($\Delta^{5,24(28)}$-stigmastadiene-3β-ol).[10]

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(6) P. R. Moore and C. A. Baumann, *J. Biol. Chem.*, **195**, 615 (1952).

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The abundance of C_{24}-epimeric sterols in nature s well recognized. The origin of these epimers can be explained by considering them as biological reduction products of a C_{24}–C_{28} unsaturated precursor. Indeed, fucosterol, the corresponding sterol in the C_{29}-series, has been isolated from algae.[11,12] The isolation of 24-methylenecholesterol explains the origin of C_{24}-epimers in the C_{28}-series and strengthens the biological reduction hypothesis.

Bergmann[13] has suggested that haliclonasterol and palysterol may be C_{20}-epimers on the basis of molecular rotational data and the present status of C_{24}–C_{28} unsaturated compounds suggests that a 20-methylenecholesterol also may occur in nature.

Experimental[14]

Preparation of Crude Sterols.—In a typical preparation of oyster sterols 8.75 lb. of fresh oysters were extracted with acetone in a Soxhlet for 48 hours. The acetone was removed and the fat (88 g., 2.22%) extracted into ether. The fat then was taken up in acetone and the phosphatides (6.7 g.) filtered off. The fat was saponified in the usual manner with alcoholic KOH and the non-saponifiable portion (10.9%) was extracted into ether. The sterols were precipitated with digitonin from an alcoholic solution of the non-saponifiables in the usual manner (18.9 g. digitonides). The digitonides were decomposed with pyridine[15] and the sterols crystallized from methanol (theory 4.72 g., 52% of non. sap.), m.p. 135–138°, $[\alpha]^{22}D$ −41.50°. The mixed sterols in alcohol showed maxima in the ultraviolet at 265, 271.5, 281 and 293 mμ. The intensities of these bands indicated the presence of 9.05% of $\Delta^{5,7}$-sterol (calcd. as ergosterol). The modified Liebermann–Burchard reaction indicated approximately the same amount of "fast-acting" sterol, thus excluding the possibility of any significant amounts of Δ^{7}, $\Delta^{8(9)}$-, $\Delta^{8(14)}$- or $\Delta^{14(15)}$-sterols in the mixture.[7,16]

Clam sterols were obtained by an identical procedure and the yields were: fat, 2.01%; acetone insoluble, 37.6% (filtered off) and non-saponifiable, 17.3% of the fat; sterol, 65.6% of the non-saponifiables calculated on the weight of digitonides.

Chromatography.—Azoyl esters were chromatographed on silicic acid:Celite, using 5.5:1 Skelly C–benzene developer exactly as previously described for the separation of plant and animal sterols.[7,17,18] In the case of oyster sterols the upper zone azoyl ester (zone 1) represents 5.02% of the total and is completely separated from zone 2 (36.13%) which in turn completely separated from zone 3 (28.55%) and zone 4 (30.30%). There is no sharp separation between zone 3 and 4 but the difference in color intensities permits an arbitrary cut of the extruded column.

The appearance of the chromatogram of clam steryl azoates was qualitatively identical to that of the oyster esters. Quantitatively there is considerably more zone 2

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(14) Melting points are uncorrected. Optical rotations were measured by means of a Rudolph precision polarimeter with photoelectric attachment. Infrared spectra were recorded with a Perkin–Elmer recording infrared spectrophotometer.

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(53.0%) in clam than in oyster. The other zones were: (1) 3.0%; (3) 21.3% and (4) 22.7%.

Purification of Zone 2 Oyster Sterol.—The azoyl ester crystallized from benzene–ethanol in fluffy needles, m.p. 193°. The ester was hydrolyzed as previously described and the acetate prepared.[17] The acetate was treated with a tenfold excess of maleic anhydride in boiling xylene for 18 hours and the provitamin D removed as previously described.[18]

The acetate of the "provitamin D-free" sterol was prepared and this reached a constant m.p. 136° after two crystallizations from ethanol. Pure zone 2 sterol, prepared by hydrolysis of the acetate, melted at 142°, $[\alpha]^{22}D$ −35.0° (26 mg. in 2 ml. of $CHCl_3$).

Anal. Calcd. for $C_{28}H_{46}O$: C, 84.35; H, 11.63. Found C, 84.40; H, 11.62.

Derivatives.—The acetate of zone 2 sterol crystallized from ethanol in plates, m.p. 136°, $[\alpha]^{22}D$ −42.4° (24 mg. in 2 ml. of $CHCl_3$).

Anal. Calcd. for $C_{30}H_{48}O_2$: C, 81.76; H, 10.98. Found: C, 81.60; H, 10.84.

The benzoate crystallized from acetone in plates, m.p. 148° (clear,153°), $[\alpha]^{29}D$ −14.1° (25 mg. in 2 ml. of $CHCl_3$).

Anal. Calcd. for $C_{35}H_{50}O_2$: C, 83.61; H, 10.02. Found: C, 83.41; H, 10.10.

Molecular rotational differences: Δ^5-sterols: Δ^1 −35 ± 16, Δ^2 +81 ± 16°; zone 2 sterol: Δ^1 −46; Δ^2 +70.

Reduction of Zone 2 Acetate.—In glacial acetic acid the reduction of 30.0 mg. of the acetate was 95% complete for two double bonds on shaking for 7 minutes with 20 mg. of pre-reduced Adams catalyst and the theoretical amount of 3.05 ml. was taken up within 20 minutes. The hydrolyzed reduction product crystallized from methanol in plates, m.p. 145°, $[\alpha]^{22}D$ +32.6° (12 mg. in 1 ml. of $CHCl_3$). The melting point was not depressed by authentic campestanol, m.p. 145°. The product gave no color with the Liebermann–Burchard reagent and showed no absorption at 6 μ in the infrared due to C=C stretching.

Anal. Calcd. for $C_{28}H_{50}O$: C, 83.51; H, 12.51. Found: C, 83.62; H, 12.63.

Derivatives.—The acetate was crystallized from ethanol, m.p. 144°, $[\alpha]^{22}D$ +18.2° (28 mg. in 2 ml. of $CHCl_3$).

Anal. Calcd. for $C_{30}H_{52}O_2$: C, 81.02; H, 11.79. Found: C, 80.93; H, 11.75.

m-Dinitrobenzoyl chloride (120 mg.), 30 mg. of zone 2 stanol and 1 ml. of pyridine were warmed on a steam-bath for 2 hours. Ten volumes of ice-cold methanol were added to the chilled mixture and the product washed with cold methanol–water. The *m*-dinitrobenzoate crystallized from benzene–ethanol in fluffy needles, m.p. 199°, mixed m.p. with authentic campestanyl *m*-dinitrobenzoate 199°, $[\alpha]^{22}D$ +22.4° (18 mg. in 2 ml. of $CHCl_3$).

Anal. Calcd. for $C_{35}H_{52}O_6N_2$: C, 70.41; H, 8.78. Found: C, 70.36; H, 8.82.

Saponification Equivalent.—Zone 2 acetate (0.800 g.) was saponified in 10.00 ml. of 0.4846 *N* alcoholic NaOH for 1 hour and the residual alkali back-titrated with 5.554 ml. of 0.5488 *N* HCl.

Anal. Calcd. for $C_{30}H_{48}O_2$: mol. wt., 440.7. Found: mol. wt., 445.

Zone 2 Clam Sterol.—This sterol was isolated and purified in an identical manner to zone 2 oyster sterol. The melting point, optical rotation, modified Liebermann–Burchard reaction and infrared spectra were identical to those of the oyster sterol. The properties of all derivatives were likewise identical.

Ozonolysis.—Seven hundred mg. of zone 2 acetate from clam was taken up as a suspension in 15 ml. of glacial acetic acid and ozonized. The exit gases were scrubbed in

a trap containing 40 ml. of ice-cold water. This trap, in turn, was connected to an indicator bottle containing acidified KI. The ozonolysis was stopped after 20 minutes, by which time the KI solution had taken on a light brown color. The acetic acid and wash water were then combined and steam distillation was carried out into a solution of dimedone. The *p*H of the solution was maintained at 5.8 by the addition of alkali and distillation was continued until the formation of dimedone derivative was negligible.

The yield of dimedone derivative, m.p. 187°, was 234 mg. (50.4% of theory for one methylene group). It crystallized from methanol–water in fluffy needles, m.p. 190°, undepressed on admixture with authentic formaldehyde dimedone.

Anal. Calcd. for $C_{17}H_{24}O_4$: C, 69.82; H, 8.27. Found: C, 69.87, 69.94; H, 8.24, 8.30.

24-Ketocholesteryl Acetate by Ozonolysis.—Two hundred and forty mg. of zone 2 acetate from oyster was dissolved in 50 ml. of acetic acid (3 times distilled over chromic oxide) held at 17°, and ozone was admitted at a rate of 1.68 mg. per minute. Ozonolysis was continued for 13.8 minutes (theory for 90% saturation for 1 double bond). The acetic acid solution was diluted with 150 ml. of water and the formaldehyde distilled off and trapped in dimedone (87 mg. identified as previously described). The aqueous acid solution was extracted with chloroform and the chloroform was washed with sodium carbonate followed by water and the sterol residue obtained by distillation *in vacuo*. The residue was taken up in benzene and chromatographed on silicic acid–Celite.[7] The first material off the column (25 mg.) was unchanged zone 2 steryl acetate, m.p. 136°. The column was then washed with benzene containing 2% chloroform and on evaporation of the solvent a solid residue, 130 mg., m.p. 126–127°, was obtained. Recrystallization from ethanol gave 24-ketocholesteryl acetate, m.p. 127°, $[\alpha]^{23}D$ −43° (Hey, *et al.*, report 127–128°, $[\alpha]^{15}D$ −43°[10]). Synthetic 24-ketocholesterol acetate gave mixed m.p. 127°.

Anal. Calcd. for $C_{29}H_{46}O_3$: C, 76.68; H, 10.48. Found: C, 76.57; H, 10.41.

The polyoxygenated sterol remaining on the column required ether for elution.

24-Ketocholesteryl Acetate 2,4-Dinitrophenylhydrazone.—The 2,4-dinitrophenylhydrazone crystallized from ethanol had m.p. 170°. The derivative prepared from synthetic 24-ketocholesteryl acetate, m.p. 170°, gave mixed m.p. 170°.

Anal. Calcd. for $C_{35}H_{50}O_6N_4$: C, 67.50; H, 8.09. Found: C, 67.49; H, 7.98.

24-Ketocholesteryl Acetate Oxime.—A solution of 15 mg. of 24-ketocholesteryl acetate and 15 mg. of hydroxylamine hydrochloride in 4 drops of anhydrous pyridine and 4 drops of absolute ethanol were warmed on the steam-bath for 1.7 hours. The addition of water precipitated the oxime, m.p. 168°. Repeated recrystallization from aqueous ethanol did not raise the melting point above 169° (Riegel and Kaye report 155–158.5°[9]). Melting point of the oxime of synthetic 24-ketocholesteryl acetate 169°, mixed m.p. 169°.

Anal. Calcd. for $C_{29}H_{47}O_3N$: C, 76.10; H, 10.35; N, 3.06. Found: C, 76.22; H, 10.46; N, 2.95.

24-Ketocholesterol.—The acetate was hydrolyzed and 24-ketocholesterol crystallized from aqueous ethanol had m.p. 137°, $[\alpha]^{30}D$ −37° (137–138.5°, $[\alpha]^{25}D$ −37°[9]); mixed m.p. with synthetic 24-ketocholesterol 137°.

Anal. Calcd. for $C_{27}H_{44}O_2$: C, 80.94; H, 11.07. Found: C, 80.86; H, 11.03.

Acknowledgment.—We are indebted to Dr. Byron Riegel, G. D. Searle and Co., Chicago, Ill., for a generous sample of synthetic 24-ketocholes-

terol, and to Dr. H. A. Schuette, Wisconsin University, for a generous sample of campesterol. Dr. R. H. Wright, British Columbia Research Council, kindly recorded infrared spectra. Dr. W. J. Whittingham, National Research Council, gave valuable assistance interpreting infrared spectra, and Mr. R. Barker and Mr. A. P. Ronald of our instrumentation section obtained many of the analytical data.

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Studies on the Conversion of Fish Stickwater to Solubles

I. The Bacterial Decomposition of Stickwater at High Temperatures

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Fish stickwater, also referred to as press water, is a by-product of the fish-processing industry. It consists of the fluids expressed from cooked fish or fish waste materials when the latter are converted to meal. After removal of the greater part of the oil by centrifugation, the stickwater can be condensed to a product called solubles which contains, usually, about 50 per cent solids. If no further treatment than evaporation were involved in the preparation of solubles, the product would be too viscous and would contain too much oil to be suitable for commerce. This unsatisfactory viscosity and oil content results primarily from the presence of suspended and dissolved protein in the original stickwater. Various methods have been devised to overcome the effects of this protein. In one process, the protein is coagulated with acid and removed by centrifugation (Lassen, 1945); in another, the protein molecules are converted to small fragments using proteolytic enzymes (Gunther and Sair, 1948). It is the purpose of the present program to devise the best method of preparing solubles from stickwater obtained from Pacific coast herring.

To treat stickwater with commercially available proteolytic enzymes, the temperature must not exceed 140 F (60 C). In as much as stickwater leaves the previous stage of processing at temperatures above 200 F (93 C), it must be cooled to 140 F. Without special cooling facilities and with the large volumes of stickwater involved, cooling to the desired temperature can

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take as long as 48 hours under plant conditions. During this time, as much as 15 to 20 per cent loss in solids from the stickwater has been found to take place. In spite of the relatively high temperatures involved, this solids loss has been found to be due to the action of bacteria. The characteristics of this bacterial decomposition of stickwater at high temperatures are the subject of the present report.

Materials and Methods

It was not possible to duplicate in the laboratory the exact conditions prevailing in a plant when a large volume of stickwater is cooled from 200 F to 140 F. Instead, 750-ml samples of stickwater in pyrex bottles each covered with a watch-glass were held at arbitrarily selected temperatures between 140 F and 200 F in thermostatically controlled glycerol baths.

Source of stickwater. Supplies of stickwater were obtained from a local plant. Samples of fresh stickwater at temperatures between 180 and 200 F were collected in cans, cooled quickly and stored at −10 F until ready for use. It was established that cooling and reheating did not affect the way in which stickwater decomposed at high temperatures.

Total solids. Ten-ml samples of stickwater were evaporated to dryness and brought to constant weight using infra-red lamps. To compensate for loss of water due to evaporation between samplings, the volume of the stickwater was readjusted to the level prevailing immediately after the previous sampling, before each new sample was taken.

Bacterial counts. To provide suitable media for bacterial counts, stickwater was first boiled for five minutes to coagulate protein and then centrifuged at 20,000 x gravity until clear. Solid medium was prepared by adding 1.5 per cent agar to the clarified stickwater. For the growth of anaerobes 0.2 per cent sodium thioglycollate was also included in the medium and counts were made using Brewer plates. All plates were incubated at 60 C for 48 hours before counts were made.

Results

Stickwater was held at constant temperatures of 180 F (82.2 C), 160 F (71.3 C) and 140 F (60 C) for 48 hours and the total solids content determined initially and finally in each case. A loss of nearly 14 per cent of the total solids was observed at 140 F and smaller

losses occurred at 160 F and 180 F (table 1). A further subdivision of temperature was made and the experiment repeated with storage temperatures of 140, 150 and 160 F. Again, the results showed that the greatest solids loss occurred at 140 F, and it was also found that considerable loss took place at 150 F (65.6 C). As the greatest loss of solids was observed at 140 F, this temperature was selected for most of the subsequent work.

That the loss in solids, even at the high temperatures involved, results from the action of bacteria is apparent from the following experiments. In one experiment, the total solids content of a sample of stickwater was determined at ten-hour intervals for a period of 50

TABLE 1. *Effect on the loss of total solids of holding stickwater at various temperatures for 48 hours*

	Experiment A			Experiment B		
Storage temperature, F	140	160	180	140	150	160
Total solids, grams per liter						
0 hr.	90.5	90.5	90.5	88.1	88.1	88.1
48 hr.	78.1	85.6	88.2	76.2	80.6	83.8
Loss of total solids, per cent	13.7	5.4	2.5	13.6	8.6	4.9

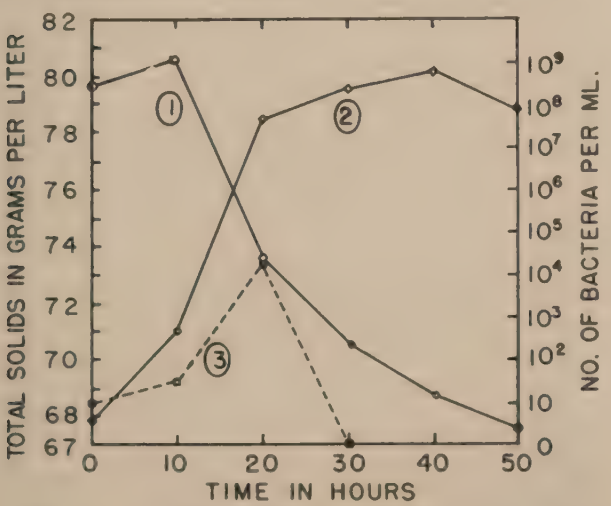

FIG. 1. Loss of total solids and change in bacterial numbers with time in herring stickwater held at 140 F (60 C). Curve 1, change in solids content; curve 2, number of anaerobes; curve 3, number of aerobes.

hours. At each time interval a count was made of the number of aerobic and anaerobic bacteria present in the stickwater. The results (figure 1) reveal that the bacterial population of the stickwater increased with time, and as it did so the solids content of the stickwater decreased. It appears significant that there is a ten-hour lag period preceding any appreciable change in the size of the bacterial population, while over the same time interval no loss in solids took place. Following this lag, a very great increase in the bacterial population took place between 10 and 20 hours, and this change in population was accompanied by a marked loss in solids. It is also of interest that the maximum number of aerobes was recorded after 20 hours while none could be detected after 30 hours. It is most probable that the aerobic organisms died out after utilizing all of the available oxygen in the stickwater. In the same experiment, the change in pH of the stickwater over the 50-hour period was also recorded. It was found to rise progressively from an initial value of 6.5 to a final one of 7.5 over the interval.

To further relate solids loss to the activities of the bacterial population, one sample of stickwater was boiled vigorously for 5 minutes, a second was autoclaved at 120 C for 30 minutes and a third was left untreated. All three samples were held at 140 F for 48 hours. Total solids were determined at the beginning and at the end of the experiment. The results in table 2 reveal that only in the autoclaved sample was there no appreciable loss in solids. Preliminary boiling, on the other hand, did not prevent solids loss. Since boiling will kill vegetative bacterial cells but not spores, and autoclaving under the conditions indicated will usually kill both, it is evident that spore-forming bacteria are primarily responsible for the loss in solids from stickwater held at 140 F.

In an attempt to reproduce the loss of solids from stickwater during storage, an anaerobic organism was isolated from the stickwater in pure culture. Morphologically, this gram positive, anaerobic, spore-forming rod resembled members of the genus Clostridium. When inoculated into a sterilized sample of stickwater and incubated at 140 F for two days, a 7.3 per cent loss of solids occurred, roughly half the loss usually obtained. It would thus appear that a considerable part, but not all, of the decomposition obtained in the stickwater is due to the action of this anaerobic spore-forming bacterium.

TABLE 2. *Effect of various heat treatments on subsequent loss of solids from stickwater upon storage at 140 F for 48 hours*

Treatment Before Holding Period	Total Solids (g per L)		Loss of Total Solids* Per cent
	0 hours	48 hours	
None	88.3	75.5	14.5
Boiled for 5 min	88.9	75.8	14.7
Autoclaved for 30 min at 120 C (248 F)	91.2	89.3	2.1

* After storage for 48 hours at 140 F.

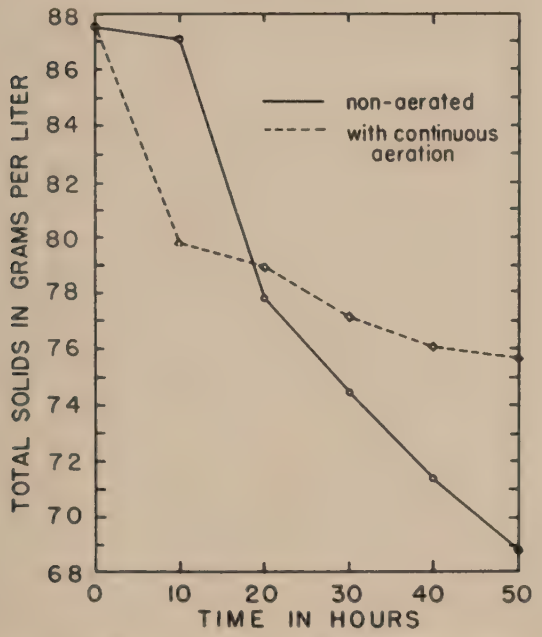

FIG. 2. Effect of aeration on change in solids content of herring stickwater with time at 140 F.

Under plant conditions, aeration has been considered as a means of speeding up the process of cooling the hot stickwater to 140 F. Therefore, it was of interest to determine the effect of aeration on the extent of the solids loss from stickwater held for 48 hours at 140 F. It is evident from figure 2 that under conditions of aeration the solids loss which occurred was about 70 per cent of that which took place under anaerobic conditions. The manner in which solids disappeared with time, however, differed. The loss in solids during the first ten hours increased from approximately 1 per cent under anaerobic conditions to almost 5 per cent under aerobic conditions.

Discussion

Thermophilic aerobic, anaerobic and facultatively aerobic spore-forming bacteria are widely distributed in nature, even in environments unfavorable for their development (Allen, 1953). Both sea water (Newton, 1924) and ocean bottom mud (Bartholomew and Rittenberg, 1949) have been found to be sources of these forms. Fish stickwater provides an excellent nutritive environment for the growth of microorganisms. One would expect, then, that because stickwater, during its production, is maintained for various periods at temperatures suitable for the growth of thermophiles, large populations of these forms would develop in it. Because of their ability to form spores capable of lying dormant in the processing equipment under unsuitable conditions, relatively large inocula of thermophiles would thus be available to bring about decomposition of subsequent batches of stickwater.

Because of the wide distribution of thermophiles in nature, one would not expect contamination of stickwater by thermophilic organisms to be a purely local problem. In support of this conclusion is the fact that stickwater samples from the two plants producing this by-product in the Vancouver area all decompose in much the same way at high temperatures. Furthermore, stickwater obtained at different seasons of the year from these plants displayed the same pattern of decomposition. In addition, it has been reported that decomposition of stickwater at a point far distant from here occurred at temperatures up to 85 C (Lassen *et al.*, 1951).

Summary

A loss in total solids takes place in herring stickwater held for 48 hours at temperatures ranging from 140 F (60 C) to 180 F (82 C). This solids loss, which can amount to as much as 15 to 20 per cent of the total solids present in stickwater at 140 F, decreases to about 2.5 per cent as the temperature increases to 180 F. When the loss of total solids with time was compared with the change in bacterial population of the stickwater over the same period, it was found that the loss in solids paralleled a corresponding rise in the bacterial population. Boiling the stickwater for 5 minutes did not reduce the amount of decomposition which could take place, but autoclaving at 120 C for 30 minutes almost completely prevented decomposition. A spore-forming

anaerobe isolated in pure culture from the stickwater, when inoculated into sterile stickwater, produced only about one-half of the total amount of decomposition obtained in unsterilized stickwater. The evidence obtained suggests that a mixed population of aerobic and anaerobic spore-forming thermophiles is responsible for the decomposition of stickwater at high temperatures.

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Studies on the Conversion of Fish Stickwater to Solubles

II. Prevention of Bacterial Decomposition of Stickwater at High Temperatures

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Previous studies (MacLeod *et al.*, 1955) have revealed that 15 to 20 per cent loss in solids can occur in herring stickwater held at 140 F (60 C) for 48 hours. Smaller losses can occur at even higher temperatures. These solids losses have been shown to be due to the action of spore-forming thermophilic bacteria.

Stickwater is currently processed by two different methods. In the one case, in which stickwater is acidulated in order to remove protein and facilitate the separation of "bound oil," the acid used also acts as a preservative (Lassen, 1945). In the other, in which proteolytic enzymes are used to treat stickwater prior to condensation to solubles, an essentially neutral medium is required and under these circumstances decomposition by thermophilic bacteria can be serious. Sodium acid pyrophosphate is the only preservative which, so far, has been suggested for use under these conditions (E. P. McFee, personal communication).

Antibiotics have been successfully employed to preserve fresh fish, meat (Tarr *et al.*, 1952, 1954), and other food products (Lundberg and Chipault, 1954). This paper describes the results obtained when a number of chemicals and antibiotics were tested to determine their ability to prevent bacterial decomposition of stickwater at high temperatures.

Materials and Methods

The materials and methods employed have been described (MacLeod *et al.*, 1955).

Preservatives were added to the stickwater at 140 F with thorough mixing, after which the mixture was stored without agitation at this temperature for 48

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hours. Sodium nitrite, versene, and sulfanilamide were each tested at levels of 1000, 100, and 10 parts per million (ppm) (table 1). All three prevented solids loss only at the 1000-ppm level. Sodium acid pyrophosphate was effective at a concentration of 0.25 per cent based on weight of the stickwater, that is, at a level of 2500 ppm. This observation confirms the finding of McFee who used rosefish stickwater (E. P. McFee, personal communication). In separate experiments, sulfathiazole was found to have a considerable though quite variable action in preventing the decomposition of stickwater. On one occasion, 10 ppm of sulfathiazole completely prevented solids loss while on another occasion, 100 ppm was only partially effective.

When antibiotics were tested, these were added to the stickwater at two levels, 1 ppm and 10 ppm, for preliminary screening purposes. Penicillin G, Achromycin, hygromycin and erythromycin were each found to be completely effective at 10 ppm, and each was also fairly effective at 1 ppm as the data in table 2 show. A great variation in effectiveness was observed with Aureomycin. On one occasion, Aureomycin was completely effective at 10 ppm and on another, 20 ppm permitted 50 per cent of the total decomposition of an untreated sample to take place.

The results obtained in the preliminary screening revealed penicillin G to be the most promising antibiotic for preserving stickwater under the conditions employed since it was the most effective of those tested, and from the economic standpoint is the least expensive. For this reason, the preservative action of penicillin G was considered in more detail.

The minimum concentration of penicillin G which would completely inhibit bacterial action at 140 F was determined (table 3). It is apparent that a level of 2 ppm is completely effective.

A temperature of 140 F, which was used in the preliminary screening experiments, would be the final temperature in the cooling process and some bacterial decomposition is known to take place above 140 F (MacLeod *et al.*, 1955). It was therefore necessary to determine if penicillin G would still be effective at higher temperatures. It was considered unlikely that the antibiotic would be subjected to any one of the higher temperatures chosen for lengths of time exceeding 10 hours. Penicillin G was thus added to stickwater at 160, 180, and 200 F and held at these temperatures for 10 hours. At the end of this time, all flasks were cooled

to 140 F and incubated for 48 hours. Solids loss at the end of the 10- and 48-hour periods was determined. The results are shown in table 4. Even 1 ppm of penicillin G retains its effectiveness in preventing decompo-

TABLE 1. *Effect of various chemicals on the total solids content of herring stickwater held at 140 F for 48 hours*

Substance Added	Level Tested	Loss of Total Solids
	ppm	*per cent*
Sodium nitrite	0	22.5
	10	20.3
	100	15.0
	1000	2.6
Versene	10	16.5
	100	16.1
	1000	4.5
Sulfanilamide	0	14.5
	10	15.8
	100	12.9
	1000	3.8
Sodium acid pyrophosphate	0	14.1
	625	14.5
	1250	7.6
	2500	0.3
	5000	−1.8

TABLE 2. *Effect of various antibiotics on the solids content of stickwater held at 140 F for 48 hours*

Experiment	Antibiotic Added	Loss in Total Solids
	1 ppm	*per cent*
1	None	20.8
	Penicillin G	3.1
	Erythromycin	6.5
2	None	18.8
	Penicillin G	3.9
	Achromycin	7.1
	Hygromycin	7.1

TABLE 3. *Level of penicillin G required to completely prevent solids loss from stickwater held at 140 F for 48 hours*

Amount of Penicillin Added	Loss of Total Solids
ppm	*per cent*
0	12.0
1	1.3
2	0.0
10	0.0

sition when stickwater is maintained at 160 F for 10 hours prior to incubating at 140 F for 48 hours. At 180 F, on the other hand, 1 ppm is only partially effective, though 10 ppm still gives complete protection. A temperature of 200 F for 10 hours greatly reduces the subsequent effectiveness of even the 10-ppm level of penicillin G.

Cooling and agitation are frequently effected by bubbling a stream of air through the stickwater. In view of this, it was necessary to determine the effectiveness of penicillin G in stickwater which was continuously aerated. An experiment similar to the previous one was carried out, that is, 10 hours holding at a temperature greater than 140 F followed by 48 hours storage at 140 F. In this case, however, the stickwater was continuously aerated during the preliminary 10-hour period. The results (table 5) show that 10 ppm of penicillin G is not so effective under conditions of aeration as it is when the stickwater is not aerated at a temperature of 180 F for 10 hours, prior to incubation at 140 F. Also, at 160 F, under conditions of aeration, 1 ppm of penicillin G is not so active in preventing solids loss as was found under anaerobic conditions (table 4). It should be noted, however, that twice as much solids are lost during the 10-hour period at 180 F under aerobic as under anaerobic conditions in the absence of penicillin G.

Because penicillin G was effective in preventing bacterial decomposition of stickwater in very low concentrations at high temperatures, one might expect

TABLE 4. *Effect of holding stickwater containing penicillin G at temperatures greater than 140 F on the ability of penicillin G to subsequently prevent solids loss at 140 F*

Temperature of Initial 10-hour Period	Amount of Penicillin G Added	Loss of Total Solids	
		After preliminary 10-hour period	After 48 hours at 140 F
F	*ppm*	*per cent*	*per cent*
160	0	0.65	16.0
	1	0.75	2.0
	10	0.75	1.2
180	0	0.00	14.6
	1	0.25	9.5
	10	0.85	1.5
200	0	0.60	15.8
	1	1.10	13.4
	10	0.75	9.8

TABLE 5. *Effect of aeration for 10 hours at various temperatures on the ability of penicillin G to subsequently prevent solids loss from stickwater maintained at 140 F for 48 hours*

Preliminary Treatment	Penicillin Added	Loss of Total Solids	
		After preliminary treatment	After 48 hours at 140 F
F	*ppm*	*per cent*	*per cent*
160 Aerated	0	5.5	15.9
	1	1.9	7.7
	10	−0.5	−1.3
180 Aerated	0	6.3	15.7
	1	5.5	6.1
	10	−0.4	6.0
180 Nonaerated	0	2.9	13.5
	1	0.9	9.2
	10	−0.6	2.6

that at room temperature the same concentrations of the antibiotic might prevent bacterial action almost indefinitely. That this is not the case, however, is shown in figure 1, where it is evident that both 10 ppm and 1 ppm are effective for little more than 72 hours.

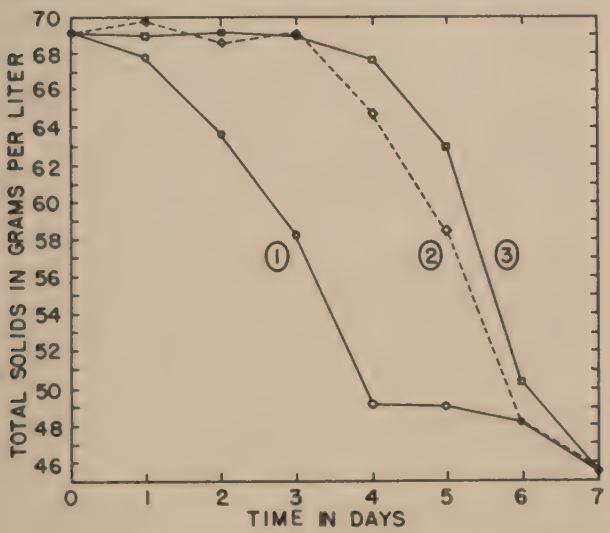

FIG. 1. The effectiveness of penicillin G in preventing solids loss from herring stickwater at room temperature. Curve 1, no added penicillin G; Curve 2, 1 ppm of penicillin G; Curve 3, 10 ppm of penicillin G.

DISCUSSION

The effects of pH and temperature on the stability of penicillin G have been quite thoroughly investigated

(Brodersen, 1947). According to Brodersen's data, after 10 hours at 160 F, 50 per cent of the added penicillin G would survive, while at 180 F, 16 per cent and at 200 F, 2 per cent would remain. From our knowledge of the amount of penicillin G required to inhibit the decomposition of stickwater at 140 F, the amount of protection obtained from the penicillin G after holding the stickwater for 10 hours at higher temperatures prior to storage at 140 F is found to agree very closely with that which can be predicted from the published stability data. On the other hand, penicillin G would be expected to survive for a much longer time than the three days during which it is able to prevent decomposition of stickwater at room temperature. In as much as the bacterial flora operative at high temperatures would not be expected to be concerned with decomposition of stickwater at room temperature, there is no necessary relation between the ability of penicillin G to protect against bacterial action in stickwater in the two temperature ranges. It would appear that at room temperature a flora resistant to penicillin G becomes dominant in stickwater after a lag period.

Because it has been found that only a negligible amount of decomposition of stickwater took place at 180 F (MacLeod *et al.*, 1955), it would appear desirable in commercial practice to withhold the addition of penicillin G until the temperature had dropped at least to this point. If cooling from 180 to 160 F could be accomplished within ten hours, the lag period preceding the beginning of decomposition in stickwater (MacLeod *et al.*, 1955), then 1 to 2 ppm of penicillin G added at 160 F would completely prevent solids loss. Because of the decreased ability of penicillin G to prevent solids loss when stickwater is aerated at a high temperature, it is apparent that aeration for cooling and mixing should be avoided.

Adding penicillin G to stickwater at a level of 2 ppm would increase the cost of producing the finished solubles by about .06 cent per pound at the current market price of this antibiotic.

Acknowledgment

The authors are indebted to The Eli Lilly Co., Indianapolis, Indiana; Lederle Laboratories, Pearl River, N. Y.; Merck and Co., Inc., Rahway, N. J.; Chas. Pfizer and Co., Brooklyn, N. Y.; Burroughs Wellcome and Co., Tuckahoe, N. Y. and Ayerst Laboratories, N. Y. for generous samples of antibiotics.

Summary

Several chemicals and antibiotics have been tested for their ability to prevent the decomposition of stickwater by bacteria at 140 F (60 C) over a 48-hour period.

Sodium nitrite, versene, sodium acid pyrophosphate and sulfanilamide were effective only at relatively high concentrations. Sulfathiazole and Aureomycin were quite effective but showed a variable ability to prevent decomposition. Streptomycin, neomycin, and Terramycin were either ineffective or only partially effective at 10 ppm. Penicillin G, erythromycin, Achromycin, and hygromycin were completely effective at 10 ppm and each had appreciable activity at 1 ppm.

Penicillin G completely prevented bacterial decomposition of stickwater during a 48-hour period at 140 F when added at a level of 2 ppm. The effect of maintaining stickwater at temperatures above 140 F for 10 hours, with or without aeration, on the ability of penicillin G to prevent the decomposition of stickwater at 140 F was determined. At room temperature, penicillin G was found to curb bacterial action for about 72 hours.

The addition of penicillin G at a level which would prevent bacterial decomposition of stickwater at high temperatures would increase the cost of condensed solubles by about 0.06 cent per pound.

TABLE 6. *Loss of total solids from stickwater in the presence and absence of penicillin at temperatures below 140 F*

Storage Temperature	Penicillin G added	Loss in Total Solids after 48 Hours
F	*ppm*	*per cent*
140 (60 C)	0	9.1
	1	0.3
130 (55 C)	0	34.2
	1	0.5
140 (60 C)	0	15.5
	1	3.2
120 (49 C)	0	40.4
	1	0.1
110 (43 C)	0	41.4
	1	0.1
98.6 (37 C)	0	35.2
	1	−0.3

Addendum

Although the authors were primarily concerned with the decomposition of fish stickwater at temperatures of

140 F and higher, the extent and control of decomposition at somewhat lower temperatures was considered after submission of the above manuscript. Because the results obtained are striking and are of interest where treatment of stickwater by enzymes having temperature optima below 140 F may be considered, they are included here.

It is evident from table 6 that a drop in temperature of only 10 F (from 140 to 130 F) brings about a fourfold increase in the amount of solids lost from the fish stickwater stored for a 48-hour period. Losses of comparable magnitude are observed at temperatures down to 98.6 F. At these temperatures up to 40 per cent of the total solids can be converted to gaseous products and water over a 48-hour period. This loss can be either completely eliminated or reduced to negligible proportions by the addition of 1 ppm of penicillin G to the stickwater.

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THE PACIFIC SALMON (GENUS *Oncorhynchus*) OF THE CANADIAN PACIFIC COAST, WITH PARTICULAR REFERENCE TO THEIR OCCURRENCE IN OR NEAR FRESH WATER

by

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A review of existing knowledge, with an outline of the current and proposed research programs of the Fisheries Research Board of Canada, prepared for the information of the Committee on Biology and Research of the International North Pacific Fisheries Commission.

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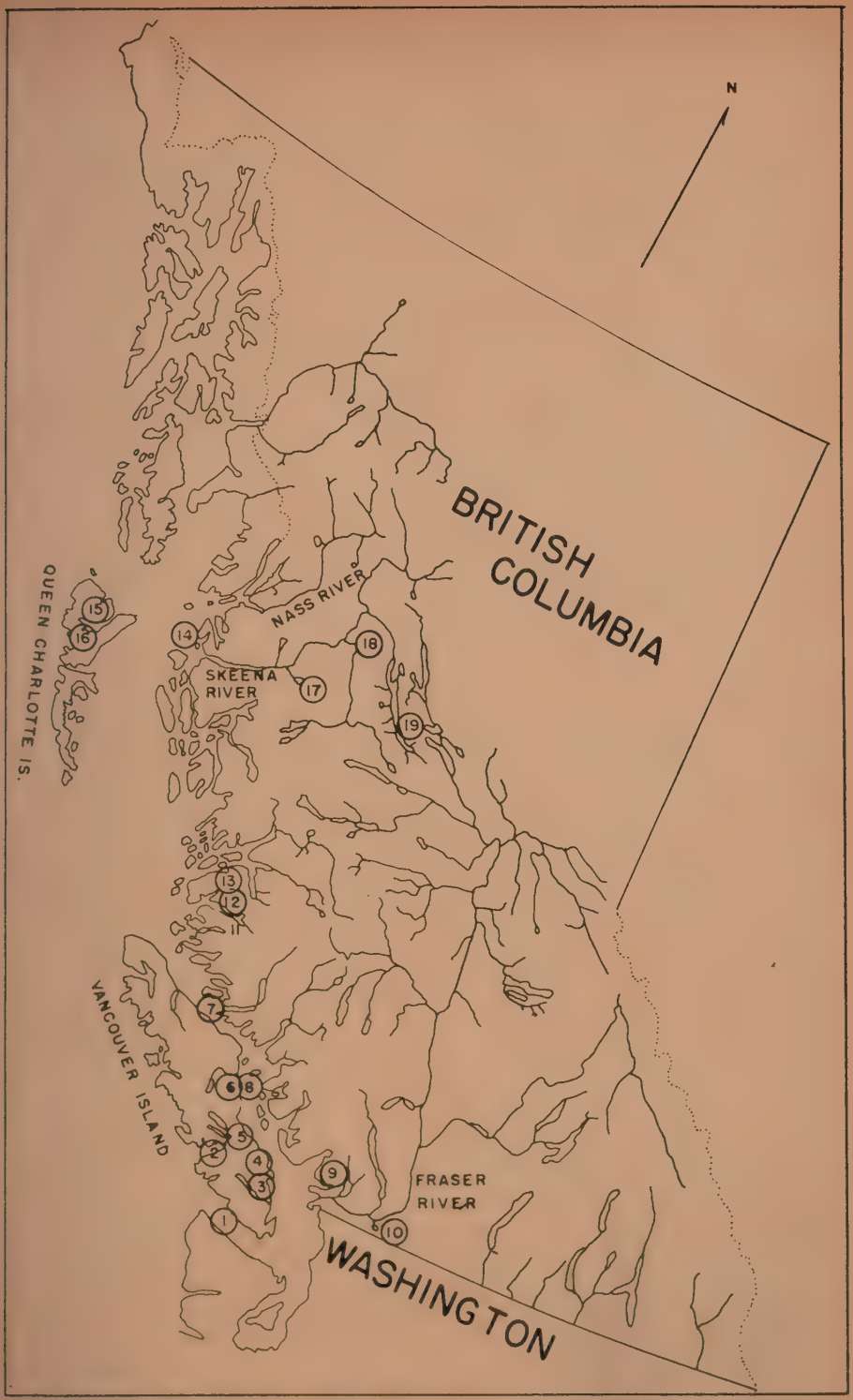

FIGURE 1. Map of the Canadian Pacific coast and the Province of British Columbia, showing important coastal areas, river systems and the following points of particular significance referred to in the text:

(1) Strait of Juan de Fuca, (2) Alberni Canal, (3) Cowichan River, (4) Nanaimo, (5) Nile Creek, (6) Morrison Creek, (7) Johnstone Strait, (8) Strait of Georgia, (9) Vancouver, (10) Cultus Lake, (11) Smith Inlet, (12) Rivers Inlet, (13) Port John, (14) Prince Rupert, (15) Massett Inlet, (16) McClinton Creek, (17) Lakelse Lake, (18) Moricetown Falls, (19) Babine Lake.

THE PACIFIC SALMON (GENUS *Oncorhynchus*) OF THE CANADIAN PACIFIC COAST, WITH PARTICULAR REFERENCE TO THEIR OCCURRENCE IN OR NEAR FRESH WATER

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Apart from a system of exchange or barter, among the aboriginal Indian tribes, of salmon—either fresh, dried or smoked—for other commodities, the first commercial fishing operations in British Columbia date from as early as 1829 when the Hudson's Bay Company purchased supplies of salmon from Fraser River Indians for pickling in barrels. A relatively small trade of this kind continued for many years. In 1870 the first salmon cannery was established on the Fraser River and from that date on the commercial exploitation of British Columbia salmon rapidly increased. Sockeye salmon (*O. nerka*) was the first species utilized but as markets developed other species became commercially important and were abundantly utilized.

Salmon Fishery

(a) Methods

At the present time salmon fishing is conducted in the estuaries of all the main rivers, and along the whole B.C. coast and the catch amounts to around 22 million dollars (market value around 48 million). Various methods of fishing are employed: gill-netting and seining, particularly for sockeye (*O. nerka*), pinks (*O. gorbuscha*), and chums (*O. keta*); gill-netting and trolling for spring (*O. tshawytscha*), and coho (*O. kisutch*). Traps are operated only at the south end of Vancouver Island and take all species. Spring and coho salmon and some pinks are also taken by anglers in inshore protected waters.

(b) Fishing Areas

Gill-netting and seining are undertaken principally in the inshore coastal channels and inlets and in the river estuaries where the fish, on spawning migration, tend to be congregated in relatively large numbers. Trolling, however, is conducted in both inshore and offshore waters, as far out as 25 miles or so. No attempt has been made to explore the fishing possibilities further to sea since the salmon must come into inshore areas to reach the spawning streams. The further offshore the fishery proceeds the higher the cost of operation.

(c) Trends in the Populations

For those species caught principally by net fishing—sockeye, pink and chum salmon—a simple comparison of the annual catches, expressed as cases* of salmon packed, gives as reasonably reliable a general understanding of the population trends as can be obtained. Such a comparison takes no account of changes in the fishery due to economic factors prevailing in certain years;

* A case of salmon consists of 48 one pound or 96 half pound cans and is equivalent, approximately, to 70 pounds of salmon, round weight.

it takes no account of the size of the other portion of the population, the spawning escapement. These are not deemed to affect appreciably the general overall picture, since (a) drastic economic conditions occur only in occasional years, and (b) the size of the spawning escapement appears to be generally proportional to the size of the catch. (In any event, no accurate long-term measure of the escapement is available.)

Sockeye Salmon. For sockeye salmon in three of the major river systems of British Columbia the annual commercial packs (cases of canned salmon) from 1917 to 1952 are graphed in the accompanying Figure 1. A line representing a moving average of 5 is added in each graph to illustrate the general trend.

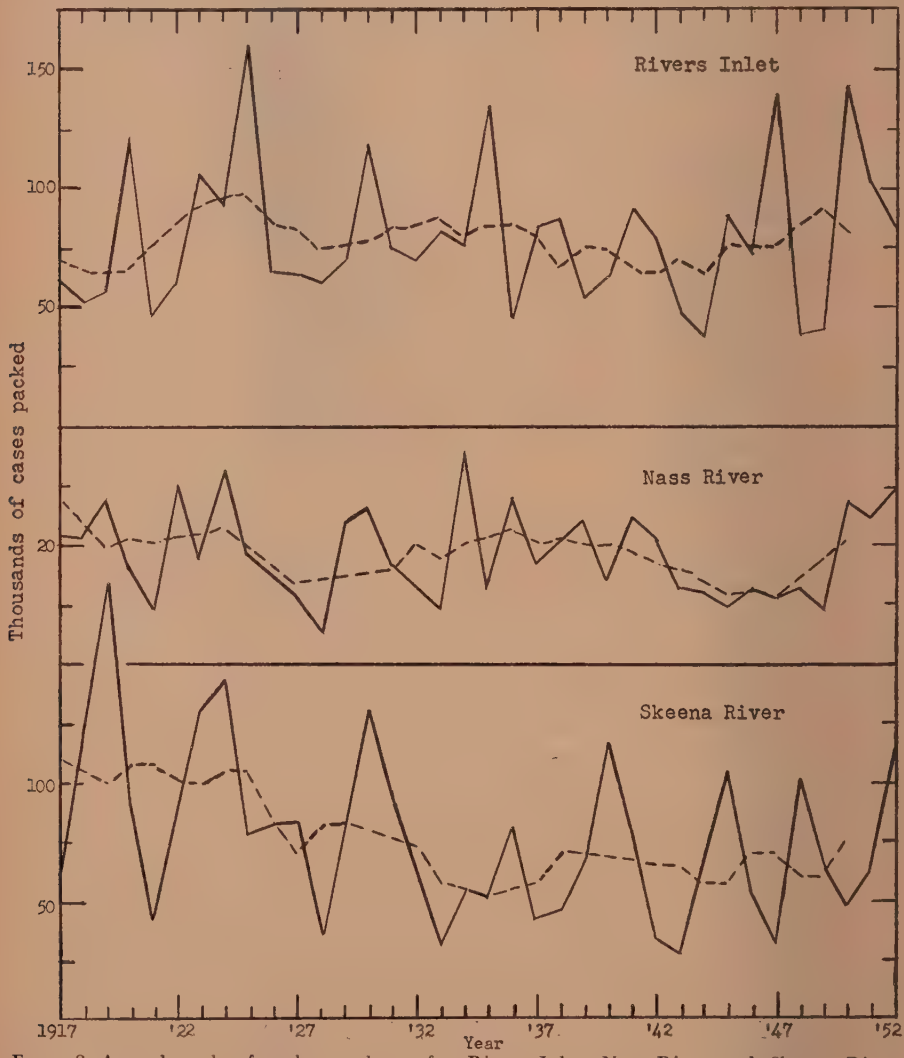

FIGURE 2. Annual pack of sockeye salmon for Rivers Inlet, Nass River and Skeena River, 1917-1952. Broken trend line is represented by a moving average of each 5 years.

For the Skeena River a decrease in the pack has occurred, if the statistics for early years are comparable with those of recent seasons. A break-down into periods shows the change in average pack per period as: 1917-1922: 100,365 cases; 1923-1932: 91,850 cases; 1933-1942: 61,079 cases; 1943-1952: 67,736 cases. There appears to be an increase in the trend for the Skeena in the last decade, perhaps partially the result of moving the upper fishing boundaries downriver some 7 miles in 1935. Although this tended to concentrate the fishing more in the lower river and cause more boats to fish off the mouth.

For the Nass River, the trend of the packs has been slightly downward (1917-1922: 21,491 cases; 1923-1932: 17,742 cases; 1933-1942: 21,042 cases; 1943-1952: 16,331 cases) although substantial increases are noted in the last three seasons, with escapements reported as quite satisfactory.

For Rivers Inlet, notwithstanding a period (1936-1946) of relatively low catches, the trend has been comparatively stable since 1927, viz. 1917-1922: 79,822 cases per year; 1923-1932: 88,730 cases; 1933-1942: 80,478 cases; 1943-1952: 79,432 cases. Spawning ground reports indicate heavy spawning escapements in the last three seasons.

For the sockeye salmon fishery, therefore, in the three areas referred to, the situation appears to be reasonably promising. Future trends will be closely followed. If indications are found that spawning escapements can be reduced and yet provide sufficient seeding, this can be quickly brought about by relaxing some of the present fishing restrictions.

In the above discussion of sockeye salmon no reference has been made to the Fraser River sockeye salmon fishery, one which, prior to 1913, was of major importance to British Columbia, particularly in every fourth year, 1901, 1905, 1909, 1913, when the "big year" run occurred. A rock slide in the river at Hell's Gate (195, pp. 17-42) in 1913, which severely blocked the ascent of the salmon of that season, and subsequent heavy fishing in 1917 reduced the "big" year to the level, approximately, of the other three years of the four year cycle of Fraser River sockeye. For the up-river nursery lake areas in which the dominant runs were bred the ratio of dominant to "off" years dropped from an average of 130:1 or more (210) to around 1.4:1 until 1930 when a new dominant run in one area, Shuswap Lake, developed, increasing about 500-fold between 1922 and 1942 (210).

Because the Fraser River sockeye runs, during migration from ocean to river, were exploited by both United States and Canadian fishermen rehabilitation and management were not undertaken until 1937 when, by treaty between Canada and the United States, the International Pacific Salmon Fisheries Commission was established. Thereby regulations applying to fishermen of both nations could be enacted and conservation projects jointly financed. Statistics pertaining to the fishery from 1938 on are contained in the Annual Reports of the International Pacific Salmon Fisheries Commission, New Westminster, B.C. Summarizations are included in the Annual Reports of the Provincial Fisheries Department, Victoria, B.C. Data for years prior to 1938

are given in the latter as well as in the Annual Reports of the Federal Department of Fisheries, Ottawa, Canada, for all years.

Pink and Chum Salmon. In Figure 2 are graphed the total pink and chum salmon canned packs for the whole of the B.C. coast from 1919-1952, with again a moving average of 5 to indicate the trends. For pink salmon the pack trend has been fairly uniform although as reported by Hoar (107) "some concern should be shown for the declining pink (and chum) catches in northern rivers—Nass and Skeena. The analysis suggests that either the environmental conditions are becoming progressively less favourable or the fishing pressure is too great."

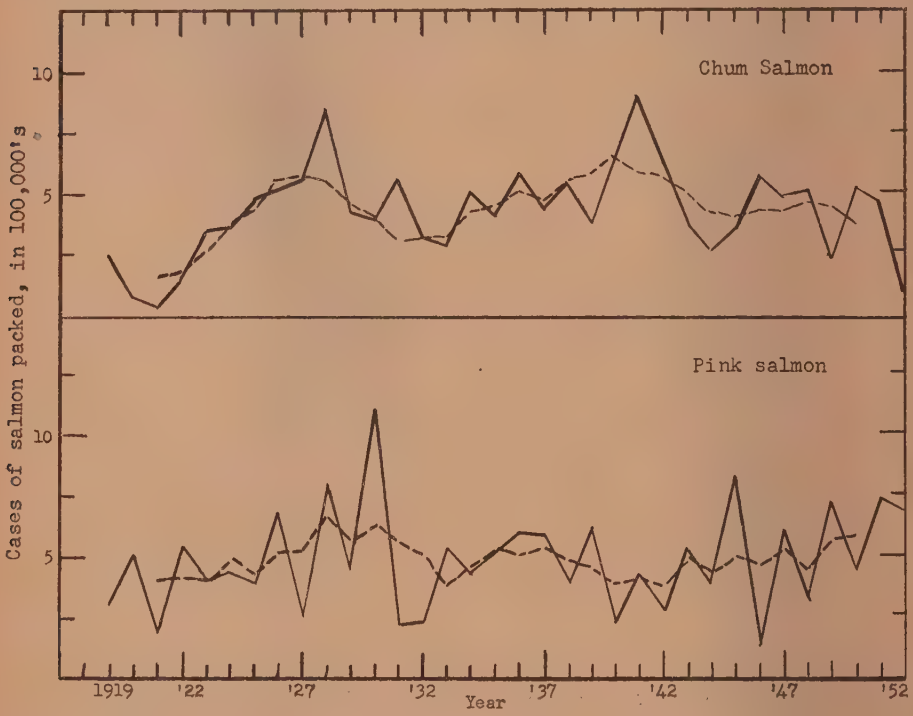

FIGURE 3. Annual pack of pink and chum salmon for the whole British Columbia coast, 1919-1952. The trend line (broken line) is shown as a moving average of each 5 year period.

For chum salmon it is recognized that the canned pack records are not too representative of chum salmon populations or catch in recent years since an increasing quantity of the species is used in the frozen and dry-salted salmon trade. Hoar (107) reports that "a real scarcity of chums was experienced in the early '40's and it seems highly probable that the stocks were low in the early '20's and '30's . . . The extreme variability of chum catches is emphasized . . ." As noted above, Hoar stresses the significance of declining catches of chums in northern areas. He also recommends a search for means to eliminate the extreme variability demonstrated in chum catches.

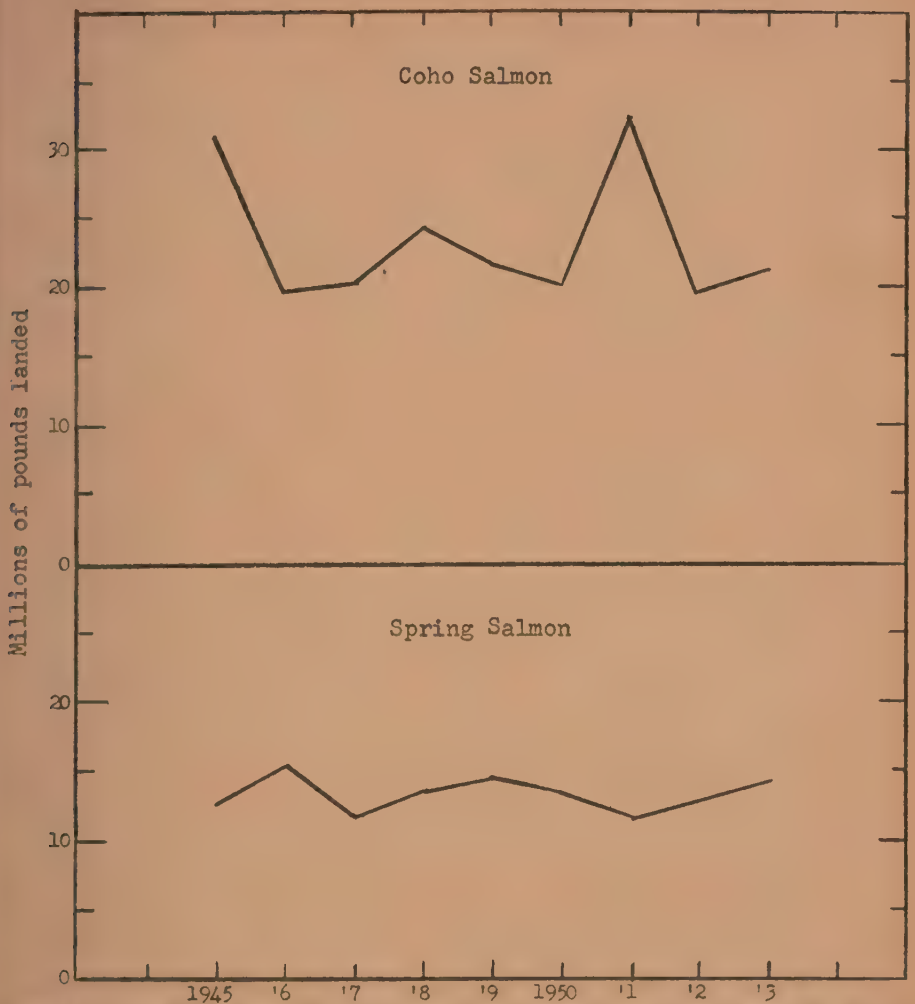

FIGURE 4. Landings of coho (*O. kisutch*) and spring (*O. tshawytscha*) salmon in British Columbia waters, 1945 to 1951. Landings not segregated by species prior to 1945. Poundage represents mixed "dressed" and "round" weights.

Spring and Coho Salmon. The trends of the catches of these two species are show in Figure 3, from 1945 to 1953. Prior to 1945 some of the landings were not segregated as to species. For spring salmon the total landings have been relatively uniform each year, the average catch, 1951-1953, amounting to approximately 14,000,000 pounds, of which 70 per cent was taken by troll, 25 per cent by gill-net, 3 per cent by seine and 2 per cent by the Sooke traps. For coho, the landings fluctuated greatly in certain years, 1945 and 1951, rising to over 30 million pounds. The average catch, 1951-1953, amounted to 24,000,000 pounds, of which 70 per cent was taken by the troll fishery, 16 per cent by gill-net, 13 per cent by seine and 1 per cent by trap. It is estimated that about 2,000 trollers operated around 1,500 boats for a total of approximately 125,000

fishing days per year. In addition to the commercial fishing, probably 10,000 anglers were active in sport fishing for spring and coho salmon, catching probably a total of 1 to 2 million pounds of both species.

Fishery Regulations

The main purpose of existing fishery regulations for salmon is to so control the periods of fishing that as the salmon appear in the fishing areas each season sufficient will be allowed to pass through unmolested to provide an adequate seeding of the spawning grounds. This is achieved mainly by setting seasonal opening and closing dates for the fishery and by instituting weekly closed periods (48 hours or longer) to permit segments of the run to escape during the migration period. The setting of an opening date has little significance from the conservation point of view; it serves essentially as a convenient time when fishing in the various districts may commence. The closing date assures that salmon in an advancing state of maturity will not be taken; it does tend to protect late-running fish. Weekly closed periods ensure that throughout the fishing season regular escapement of salmon occurs. The basic closed period is 48 hours but a formula has been devised (Special Regulatory Measures—Salmon Net Fishing—Fisheries District No. 2, B.C. of March 18, 1949) whereby if the gear in use in certain areas exceeds a stated amount the weekly closure is increased. The intent is to have the weekly closed periods conform, in ratio, to the amount of gear in operation. In addition the Department of Fisheries has authority to place extra closures or restriction on fishing in any area or at any time when it is indicated or seems apparent that spawning escapements are too light, i.e. that exploitation is too severe.

There are other regulations which have to do with:

(a) stipulating the minimum sizes of mesh to be used in certain areas or at certain periods,

(b) specifying the maximum length and depth of nets,

(c) prohibiting the use of fishing gear in specified waters, particularly in the vicinity of stream mouths, etc.,

(d) limiting the use of certain types of gear, principally seines, in particular areas to specified periods of the season,

(e) prohibiting the capture or molestation of salmon during migration to the spawning grounds, except that at specific tribal fishing sites native Indians are granted permits to take salmon, for food purposes only, by recognized fishing methods.

Fish Protection

All salmon areas of the Province, both coastal and interior, are divided up into administrative districts in each of which one or more Fishery Inspectors keep a close check on river and stream conditions throughout the year and, in particular, make observations on the migration and spawning of the salmon. Any obstructions or hazards to upstream migration are removed where feasible or reported for expert attention, fishing by Indians is supervised, poaching is closely watched for, evidences of pollution are looked for and reported.

In short, every effort is made to assure, for the salmon which constitute the spawning escapement, as satisfactory conditions for deposition of eggs as can be arranged. Particularly where logging operations are being conducted the Inspectors endeavour to ensure that there will be no obstruction to salmon migration or damage to spawning areas by formation of log jams, dumping of debris in the streams, etc.; where portable sawmills are operated steps are taken to ensure that piling of sawdust in areas adjacent to streams can have no deleterious effect on the survival of eggs or fry.

In addition the Inspectors make annual estimations of the size of the spawning salmon run to each stream in their area and general observations on the probable success of spawning. As many observations as possible are also made of fry hatch and downstream movement of fry or fingerlings. These records are of use in setting up rough prediction indices of the probable size of the returning cycle runs of each species. It might be added that these many and varied observations contained in the files of the Department are of great value to current scientific studies and will increase in significance as the Inspectors gain more experience in their respective areas.

Salmon Research

Apart from a few studies conducted by C. McLean Fraser (100-103) and a series of reports on the sockeye runs to major B.C. rivers, begun by Gilbert in 1913 (105) it may be said that fisheries research in B.C. began in 1924 when a full-time Director and a small staff of biologists were appointed to the Pacific Biological Station at Departure Bay, Nanaimo, B.C. Researches were commenced on salmon migration and on sockeye salmon propagation. As the commercial fishery expanded and its intensity increased greater concern was felt for the maintenance of the stocks. Information was desired as to whether prevailing regulations were adequately meeting the needs of optimum utilization of the natural resource. Where declines in catches had occurred it was desired to know whether these were the result of over-fishing or a decrease in natural production in the lakes and streams. It was felt that where feasible some effort should be made to reduce the large fluctuations occurring from year to year in the populations of salmon or at least to ascertain the causative factors. Moreover it was recognized that if more accurate measures of prediction or forecast of the sizes of runs returning from the ocean could be devised, such would be exceedingly useful. Research was therefore extended to assess the factors affecting and limiting natural production. This involved also a closer examination of the life-history of the fish and the relation of environment to their well-being.

Research on salmon, more particularly that of a fundamental nature, has advanced appreciably in the intervening thirty years and in the appendices which follow the information obtained is briefly outlined, together with such plans as can be given of proposed research. Some of the studies apply to specific species. They are dealt with in Appendices I-IV. Others, Appendices V-VIII, are of a more general nature and may have application to several or

all species. In Appendix VIII is given a statement of the proposed salmon research programs required to answer current problems. As complete a bibliography as possible has been prepared (Appendix IX) of Canadian Pacific salmon research and where the brief summaries do not provide sufficient data for the reader, reference is made to the literature where further information may be obtained.

Some unpublished material has been taken from the Summary Reports of the Pacific Biological Station which are prepared each year as Appendices to the Annual Report of the Director of the Station. The Summary Reports consist of brief statements of research conducted and results obtained during the year by the Station's scientists. The information is considered to be of a confidential nature and not for publication, but for the purposes of this review the compiler has felt it permissible to utilize whatever material is required to give a good general picture of the projects investigated and the results obtained.

Acknowledgements

In the preparation of this review the author has had the active collaboration of a number of colleagues on the staff of the Pacific Biological Station: Dr. Ferris Neave and Messrs. Hunter and Wickett for pink and chum salmon; Dr. D. J. Milne for spring and coho; Messrs. Withler, Shepard and Foskett for sockeye salmon; Dr. J. R. Brett for Experimental Biology. Every effort has been made to make the bibliography complete; if any omissions have occurred humble apologies are extended.

APPENDIX I

Research on Sockeye Salmon *(Oncorhynchus nerka)*

I. Information for Regulation

A. Studies of migration in coastal waters and river estuaries by tagging and marking.

In **tagging** experiments adult salmon are caught at selected fishing locations, and numbered tags affixed. The distribution along the coast and to coastal rivers is revealed by the recovery of tagged individuals. In **marking** experiments, on the other hand, young salmon are captured in selected streams, distinctively marked by removal of certain fins, and released to proceed seaward; recoveries of marked adults throughout the fishing areas demonstrate the ocean distribution. The two methods are, therefore, essentially complementary, **tagging** showing the general source of the populations of salmon that pass through specific fishing areas, **marking** revealing the coastal distribution of fish from a known area of origin.

Coastal tagging programs have been few in number and confined to inshore coastal areas, largely due to the inability to obtain fish for tagging in sufficient

quantity in more offshore regions. Taggings were made in the south, Strait of Juan de Fuca (143), in the north off the Nass River (224,225) and in a coastal channel, Johnstone Strait (224,225). Recoveries were obtained from adjacent rivers and intervening fishing areas and varied from 20 per cent to 27 per cent of tags used. Migratory paths were indicated and speed of migration revealed—10 miles per day in the south, a rate of 4 miles per hour (four specimens) and 95 miles in 24 hours (3 specimens) in the north.

The Strait of Juan de Fuca tagging (143) produced a few (fifty) recoveries in the Fraser River system. The quite fragmentary data suggest that sockeye going furthest upriver run earlier and that the bulk of the fish going to upriver spawning areas are to be found in the fishing areas at the height of the fishing season.

In the course of the Johnstone Strait tagging operations (224), experiments were undertaken (44) to determine the relation of the olfactory sense to migration. A total of 259 sockeye were released after the olfactory nerves had been severed, along with 254 normal fish. Of the latter, 65 were recovered; of the former, 42. The results were inconclusive but suggested that "the elimination of olfactory sensibility appears definitely to interfere to some extent with the migration."

Tagging experiments in river estuaries have been conducted chiefly in the Skeena River (6, 122, 175, 179, 180, 184). One preliminary tagging was undertaken on the Fraser River (11) in 1930 which indicated that sockeye make the transfer from salt to fresh water in a gradual and rather leisurely manner and that once in the river proper their upstream migration speed (5 specimens) is approximately 4 miles per day. The Skeena River taggings, conducted for 5 seasons, revealed that:

(a) the fishery removed an average of 27.4 per cent of total tagged fish used (6). Allowing for loss of tags, tagging mortality, etc., it is suggested that around 50 per cent of the sockeye population is taken by the fishing fleet.

(b) the upriver Indian fishery removed 9.2 per cent of the total tagged fish.

(c) about 50 days are required to reach remote Babine Lake spawning streams.

(d) upstream movement takes place at approximately 11 miles per day.

(e) certain lower Skeena spawning areas have early sockeye runs.

(f) there was no indication of furthermost sockeye races entering the river and the fishing areas earlier.

(g) since about five days are required for the sockeye to move from the river mouth to above the upriver fishing boundary, the 48-hour weekly closure is of limited value.

Marking experiments have been conducted on the Fraser River (72), on the Skeena (4) and at a central coastal area, Port John. The recoveries of marked adults have shown the migratory paths through the fishing areas, the time of occurrence of the runs, the extent of commercial exploitation—50 per cent to 75 per cent -and the percentage return—10 per cent in one series of

experiments (72), 3.1 per cent at Port John but with no correction for differential mortality or for removal by the fishery.

B. Sampling of catch to determine population characteristics.

In order to trace the changes, season by season, in the lengths and weights of sockeye caught, the age classes involved and the sex ratios, a long series of sampling has been conducted (2, 40, 42, 99, 105) in four of the more important sockeye salmon fishing areas of the B.C. coast, namely, the Fraser, Skeena, and Nass Rivers, and at Rivers Inlet. In 1938 the Fraser River sampling was dropped from the program (but carried on by the International Pacific Salmon Fisheries Commission) and a smaller but important fishing area in Smith Inlet added (215). For the Fraser River sockeye runs, samples were taken at the Sooke traps, therefore considered to be a sample unselected as to size or sex by type of gear, though it is now recognized that other populations of sockeye, not bound for the Fraser River, may have been involved to a minor extent, such as sockeye from west coast of Vancouver Island streams or streams in the State of Washington emptying into Puget Sound. In all other areas the samples were taken from the gill-net fishery and therefore were probably selective as to size, sex and age. The samples are, consequently, essentially samples of the commercial catch and not necessarily of the populations of sockeye in the areas and moving upriver.

A study of the samplings early showed (105) distinct age groupings for the various river systems. For example, the Fraser River sockeye consisted predominantly of 4-year fish, first year only spent in fresh water; 5-year fish, one year in fresh water, varied from 7.5 to 25 per cent but 5-year, two years in fresh water, were few—1 to 9 per cent. The Skeena River and Rivers Inlet samples were composed largely, however, of 4- and 5-year, one year in fresh water, types, the two age groups varying exceedingly from season to season. The Nass River samples, on the other hand, contained mostly 5-year, two years in fresh water, individuals (63 per cent) with 4-year, one year in lake, fish making up 18 per cent, 5-year, one year in lake, 12 per cent, and 6-year, two years in lake, 7 per cent. Smith Inlet samples resembled those of the adjacent Rivers Inlet area.

Although each season's length frequencies covered a wide range, e.g. 18 to 29 inches, the averages per age-group did not vary greatly, e.g. 1 to 1.5 inches. The average (40-1938) may be shown as:

		4_2		5_2		5_3	
River System	*Period*	*Male*	*Female*	*Male*	*Female*	*Male*	*Female*
Fraser	1920-36	23.7	22.9	25.5	24.4	23.8	23.0
Rivers Inlet	1912-36	22.5	22.4	25.4	24.7		
Skeena	1912-36	23.7	23.1	25.7	24.8	24.1	23.3
Nass	1912-36	24.5	23.7	26.2	25.2	26.2	25.3

Average weights varied similarly.

Sex ratios were also determined, varying considerably from year to year and according to age group, as follows:

River System	Period	4_2 Male	4_2 Female	5_2 Male	5_2 Female	5_3 Male	5_3 Female
Fraser	1915-37	49	51	53	47	46	54
Rivers Inlet	1915-37	63	37	35	65		
Skeena	1915-37	50	50	43	57		
Nass	1915-37	48	52	46	54	46	54

In addition to the above analyses, attention was also given (105) to growth rates, as revealed by scale patterns. They demonstrated a characteristic for the Rivers Inlet sockeye, a relatively small first year growth, followed by a relatively fast growth after the first winter and just prior to seaward migration; also, an unusually good growth in the third year (second in the sea). In association with the sampling studies a number of collections of seaward migrating sockeye from various sockeye areas were examined (105) and growth characteristics, etc. noted, as shown by the scales.

For a number of years attempts were made to forecast the size of runs coming in from the ocean on the basis of age composition of the catch sample, success of the fishery and the amount of the spawning escapement. The insufficiency of precise enough data on the latter very significant feature made the forecasts too indefinite and too broad, hence they have been latterly abandoned. An attempt has been made, however, (99) to observe and sample the spawning runs in one area, Rivers Inlet, and to compare it with the fishery and the catch sample. Preliminary observations show that the effect of the selective action of gill-net fishing gear can be quite important in heavily exploiting the large 4_2 and small 5_2 males, making relatively little use of the smallest and largest fish. The fishery likewise tends to select out the medium-sized females. It is probable that greater use of nylon gill-nets may alter appreciably the selective action found for linen thread nets.

C. Spawning escapement studies.

Each year the field officers of the Department of Fisheries make inspections of all sockeye spawning areas in order to determine the size of the spawning run and its characteristics with respect to sex ratios, proportion of small fish, general condition of the fish. The reports are summarized each season and circulated in mimeographed form. They are also reported in the annual report of the B.C. Department of Fisheries. In most northern areas the spawning grounds are located in remote, difficult-to-reach country and inspections can be made only once or twice a year. Much depends, therefore, on the conditions for observation at the time of the inspection and the coincidence of the inspection with the time of the peak of the run. For these reasons the observations are of limited value. However, they are the best that can be obtained and as the inspectors gain greater knowledge of their respective districts their observation efficiency increases. They do a very worthwhile job.

(a) **Escapement and distribution.** For the Skeena River an interesting study was made of the spawning escapement in the watershed and the distribution of sockeye to the various spawning grounds, based on weir counts at Babine Lake and inspections elsewhere (17). Average escapement to the Skeena River system for 1946 and 1947 was 678,000 fish, the extent of the spawning areas (exclusive of lake spawning) being 500,000 square yards or about 100 acres. The Babine Lake sub-system contained around 60 per cent of the total spawning area, untilized by an estimated 70 per cent of the total escapement.

Reference has already been made to the information obtained from tagging Skeena River sockeye in determining the speed of migration upriver, the proportion of the spawning escapement taken by the Indians for food purposes, and the fact that certain lower Skeena sockeye populations run early in the season whereas the two major populations are well-spread throughout the fishing season, the peaks coinciding with the time of greatest fishing effort. Some recoveries of tags have been made on the spawning grounds, thus giving some initial qualitative information but greatest recoveries have been made in areas where counting weirs are installed (175, 179, 180).

(b) **Population characteristics.** At these weir locations, also, sampling has been undertaken to determine the age-groups involved, the size frequency distributions and sex ratios, in order to ascertain the difference from year to year, and, in particular, to assess the significance as far as egg depositions and future productions are concerned (5). So far no evidence has been found in northern areas of the occurrence of strikingly dominant year-groups, such as on the Fraser (210) but rather a greater mixture of four- and five-year-old fish, such feature tending to reduce severe fluctuations in runs and render less likely any serious effect of a calamitous interference with any one spawning group.

(c) **Losses during upriver ascent.** Limited information is available of the extent of what might be termed "normal" mortality of sockeye caused by the hazards of upriver ascent, such as narrow canyons with swift, broken water, small waterfalls, rapids, etc. Gashed, wounded and net-marked adults are encountered at counting weirs to a minor extent; observations at Babine River weir indicated that from 3 per cent to 7 per cent of a representative sample of the fish bore injuries, though only probably 10 per cent of these were of a serious nature. For one natural hazard, Moricetown Falls on the Bulkley River (123), information is available on the delay produced—5.8 days for sockeye—in migration which may have an effect on successful spawning. A fishway has since been installed to make this hazard possible for fish (111).

Extensive losses can occur, however, where rock-slides obstruct the river to a considerable degree. The rock-slide in the Babine River in 1951 is an excellent example; it not only reduced the run to the upper river to around one-third of its normal size but the proportion of injured among those getting through rose to 30 per cent, many of the fish being seriously affected (106).

Further information on losses occurring in normal river ascent is desired and studies are planned for 1954.

The Harbour Seal *(Phoca vitulina richardi)* has long been accused of doing extensive damage to gill-net gear, to fish enmeshed in it and to salmon runs generally. Studies, however, indicated (50) that, in the Skeena River estuary, damage to gill-nets from seal action was negligible, loss in fish occurred chiefly in the early part of the fishing season, amounting to 12 per cent or more of the value of the catch, and that greatest depredation upon salmon probably occurs in upriver areas. It is suggested that a good measure of control may be feasible by employing one or more crews of trained hunters each season.

II. Assessment of Natural Propagation

One purpose of the present sockeye salmon research was to determine whether existing declines in catches were due to over-fishing or to a drop in the rate of natural production. Another purpose was to gain an understanding of present natural production in order to determine how it might be profitably increased. There was involved, therefore, as detailed a study as possible of all phases of natural propagation, from spawning to migration of the young salmon to the sea. All situations or occasions where loss of eggs, alevins, fry, fingerlings or smolts could occur are being examined and the extent of loss ascertained. The degree to which any losses can be avoided or reduced is being noted. In the sections that follow, each phase of the life history is dealt with from these two aspects.

Early studies at Cultus Lake, a sockeye-producing tributary of the lower Fraser River, had provided information (69, 76) concerning a sockeye area where beach spawning occurred. It was desirable to gather similar data from different kinds of areas for comparison, particularly for locations where the more normal stream spawning occurred. Investigations were therefore begun at Babine and Lakelse Lakes on the Skeena and at Port John, in the central coastal area. The results obtained to date are valuable in showing not only the overall average production to be expected but all the extent of the ranges, with explanations for the wide variations where these can be identified.

A. Spawning operations.

(a) **Potential egg deposition.** This is derived by multiplying the total number of females passing through the counting weir by the average egg content per female (231). This latter is determined by counting the eggs in a random sample of female fish. Sufficient information is now available (7, 88, 89, 230) that nomographs of the relation of egg content to size of female can be prepared, which will sufficiently-accurately indicate the egg content if the average size, a readily-obtainable datum, is obtained.

Summarized records of egg content per female are:

Area	*Average*	*Range of means*
Cultus Lake	4500	3800-4545
Lakelse Lake	3365	2587-4050
Port John	2332	1830-2632
Babine	3369	3187-3525

(b) **Sex ratios.** The relation of numbers of males to females in the spawning escapement is of considerable significance in fertilization of eggs. Although at Cultus Lake females generally predominated at least 2:1 (69, 76, 86) in other areas the sexes were more uniformly represented, sometimes with males in greater abundance (5, 112, 113, 127, 187, 231). There is at the present time some difference of opinion as to ratio of male to female spawners required on the spawning grounds. The matter is receiving attention in test plots with varying proportions of the two sexes contained therein.

(c) **Effect of water level variations.** No precise data are available. Field observations indicate that low water conditions delay the entrance of spawners into spawning streams and cause the fish to congregate in the narrow creek bed. On the contrary, high water levels cause some of the fish to spawn along the creek margins which are likely to become dry and cause loss of eggs. The problem of stream water level is of greatest moment in areas where logging is removing the forest cover and may cause flash floods and highly irregular stream flow.

(d) **Effect of prevailing water temperatures.** No precise data are available. There is some field evidence to indicate that high creek water temperatures cause mortality among unspawned fish, particularly females, prior to spawning. Such conditions do not appear to be too frequent under natural circumstances.

(e) **Losses due to predators.** No precise information is available. Observations suggest that mortality due to bear predation can at times be appreciable but not a serious matter. Similarly with the predation by birds and fishes on eggs being deposited or already deposited in redds. It is difficult to determine whether salmon eggs found in bird or fish stomachs were not infertile ones, or one not properly deposited in the redds, which would have been a total loss in any event.

(f) **Losses in unspawned females.** Under normal conditions this loss is probably a minor one. Unfortunately, where counting weirs are operated the deleterious effect of the structure, by interfering with the ready ascent of the stream or causing the fish to jump at it in order to attempt to get over, cannot be readily determined. At Babine River in 1953, of 26,000 female sockeye examined only 2 per cent were found to be unspawned; at Port John, 14 females out of 170 were recovered unspawned.

(g) **Losses due to incomplete egg release.** Examinations of spawned-out carcasses of female sockeye have revealed that little wastage of eggs occurs. Tests at Babine counting weir in 1952 indicated that only 9 per cent of the 26,000 carcasses examined were partially-spawned. No indication of the average number of eggs present was given. At Six Mile Creek, Babine, in 1940-51, losses due to egg retention were found to be 2.8 per cent of total eggs. At Cultus Lake, for beach spawning, in 1925, of 53 spawners examined, over 75 per cent contained 20 or fewer eggs; in 1935, of 417 individuals examined, the average egg content was 36.5, or less than 1 per cent. For Port John, egg loss by

incomplete expression of eggs amounted to 3.7 per cent in 1953 but only 0.73 per cent in 1954.

B. Egg incubation.

Losses occurring during the period the eggs are incubating in the redds may be attributable chiefly to (a) non-fertilization, (b) effect of inadequate water circulation which leads to suffocation, (c) effect of silting which likewise causes suffocation of eggs, (d) effect of freshets in scouring out and displacing the eggs, (e) effect of falling water levels by leaving some eggs in redds high and dry, (f) effect of below-freezing temperatures in killing the eggs in redds on high ground or along the stream margins, and (g) superimposition of eggs in already occupied redds by later-arriving sockeye or salmon of other species.

Periodic sampling of redds has been undertaken to determine the losses due to these various factors but as yet it has been difficult to separate some of them. In the case of others, such as the damaging effect of freshets, drought and superimposition, obtaining of data from the field depends upon the development of such conditions in areas where satisfactory observations can be made. The potential significance of the effect of these factors in years of uncommon climatic conditions is recognized and therefore the value of ensuring a good, even flow in important sockeye-producing streams is emphasized. This situation applies particularly to streams which have no lakes at the head, the lakes tending to provide a more even flow throughout the year.

Observations conducted on a test stream (Six Mile Creek) on Babine Lake in 1951 gave the following data:

Losses during the pre-eyed stage—7.4 per cent of the total eggs in the redd.

Losses during the eyed stage—24.5 per cent of the total eggs in the redd.

Losses during the alevin stage—undetermined but probably not less than 20 per cent of total eggs.

It was estimated that of the total loss of eggs, freezing during the unusually severe winter probably accounted for at least 30 per cent.

At Scully Creek, Lakelse Lake, per cent loss observed in redds has varied, from 40 per cent to 64 per cent.

In summary, it is estimated, pending more precise data, that the overall redd losses probably amount to around 50 per cent of eggs deposited.

C. Fry hatch and migration to lake.

Losses during this stage of the life cycle are chiefly attributed to (a) effects of severe stream conditions, i.e. flash freshets or very low water flow and (b) activities of predator fishes, i.e. trout, squawfish, sculpins, coho salmon yearlings. Losses due to unfavourable stream conditions are difficult to assess unless an extreme situation is found which can be analyzed. For predation losses, tests have indicated mortality varying from 32 per cent to 91 per cent of marked and released fry for Lakelse studies and 65 per cent for Babine. Pending

further evidence, it is estimated that fry losses in streams, due to predation and other stream conditions, amounts to around 75 per cent of hatched and emerged fry.

In summary it may be pointed out that from repeated enumerations of fry produced from known egg depositions (as indicated by the number of females ascending to spawn) the following percentage yields have been obtained:

Scully Creek, Lakelse Lake,	: 13.7, 9.3, 13.6, 12.2, 10.1
Tally Creek, Port John,	: 25.2, 1.75, 5.12, 8.9, 5.02, 13.4
Six Mile Creek, Babine,	: 12.0, 19.0
Geometric mean,	: 9.7 per cent

D. Lake residence.

For sockeye salmon, which remain in fresh water for at least one year before passing seaward, the one- or two-year lake residence is particularly significant in that during the period heavy losses can and do occur. Since this is the last stage prior to seaward migration any reduction in mortality that can be brought about will directly increase the seaward-migrating population and hence the adult return two to three years later.

Studies have shown that:

(a) young sockeye depend almost solely upon lake plankton for food (51, 63, 201, 203),

(b) growth of sockeye is inversely related to the size of the population (78),

(c) significant losses occur throughout the lake residence period (20, 77),

(d) predaceous fish are an important cause of loss of sockeye (199, 209).

The importance of understanding the relation of lake conditions to the well-being of young sockeye has resulted in studies of the physical and chemical characteristics of certain sockeye lakes and their plankton supplies and fish populations (13, 15, 25, 26, 95, 96, 117, 120, 202, 204, 205, 206, 213, 216, 229, 233.) In addition an attempt has been made to ascertain the effect upon young sockeye survival of reducing or controlling the populations of predaceous fish (74, 91, 92). Some theoretical aspects of the possibilities of success have been considered (212).

At the present time an intensive study is being made at Lakelse Lake, Skeena River system, of the relation of conditions in the lake—limnology, plankton, fish populations—to the production of young sockeye, with particular reference to the factors limiting production (20, 121). The relationship of variations in abundance of competitor and predator fishes to changes in production of younk sockeye will receive special attention (9, 10).

E. Overall percentage production of young sockeye in fresh water.

As a measure of the rate of production of sockeye, data have been obtained in four widely-differing sockeye areas in order to reach some general understanding of (a) what might be considered "normal" production, (b) what ranges in production can occur and (c) to what extent and in what way prevailing climatic or environmental conditions may affect production. The results, to

, showing the ratio of seaward-migrating sockeye smolts produced to the ntial egg deposition and expressed as percentages, may be summarized as:

Cultus Lake—lower Fraser system	—1.13, 1.05, 3.16 (69, 76)
Port John—central coastal region	—0.5, 3.0, 5.0, 3.0
Lakelse Lake—lower Skeena system	—1.1, 0.4, 1.5, 8.5(?), 1.7 (20, 84)
Babine Lake—upper Skeena system	—0.48, 0.77, 1.52, 2.0 (47, 232)
Geometric mean	—1.43

As pointed out above, an endeavour is being made to break the fresh water es down to show when or where they occur—in the redds, the streams or lakes -their relative extent and what might be done to reduce them 7, 181, 182).

F. Seaward migration of sockeye.

Aside from certain analysis of data to reveal what factors or conditions ng about seaward migration of young sockeye from a lake, e.g. the relation temperature (75), or, conversely, may tend to produce lake-resident pulations (207, 208), studies have concerned chiefly the numbers, sizes and groups of migrants (14, 20, 47, 56, 84, 112, 113, 232). Few observations have en made of the seaward migrations once the migrants have left the counting irs or sampling stations selected just below the lakes. No quantitative dies have been made of the losses occurring during seaward migration or hen they reach the river estuaries and proceed to sea nor of the particular bits or activities of the fish at this latter time.

G. Adult return from the ocean from a known smolt migration.

An inverse relationship between the size of a smolt migration (in numbers migrants) and the percentage return of adults has been shown. It is indicated at the size of the individual migrants is chiefly or entirely responsible for is, small migrants suffering greater mortality either during seaward migration ocean residence than larger smolts (85).

I. Studies Directed to Improvement of Natural Production

Any measures which can be adopted to increase the efficiency of natural ropagation would result in greater sockeye populations in the ocean and ermit a greater degree of exploitation. Various means of achieving this bjective have been studied or are being explored.

(a) **Value of artificial propagation.** In the early 1900's a number of salmon atcheries were in operation, hatching and releasing into adjacent lakes large umbers of sockeye fry. Subsequently, around 1920, planting of the eggs at he "eyed" stage in the gravel of suitable streams tributary to sockeye lakes, as believed to be more efficient and came to be widely used (106a). In 1925 tudies were commenced (54, 59) of the relative efficiencies of artificial ropagation of sockeye by both methods, release of fry and planting of "eyed" ggs, in comparison with natural propagation. Results, based on the number f seaward-migrating smolts produced, indicated (64, 69, 76) that:

(1) where a natural run of sockeye occurs with a reasonable expectancy of successful spawning, artificial propagation is unnecessary and, if producing additional results over natural spawning, these would not appear to be in any way commensurate with the cost.
(2) the egg collections for hatcheries then operating amounted to approximately 3.5 per cent of all eggs contained in the estimated spawning escapements of the three major British Columbia river systems.
(3) heavy losses (94 to 97 per cent) occur after the sockeye fry are liberated into the lake.

(b) **Predator control.** In view of the heavy lake mortality among sockeye fry, the loss due to predation was studied (74, 209) and subsequently the effect of a campaign to reduce and control the population of a predator was determined (91, 92). Evidence was presented showing an appreciable increase in sockeye survival and it was indicated that control of predators might be economically feasible.

(c) **Restocking depleted areas by transfer of eggs (80).** It was indicated that the source of the eggs was an important consideration, particularly the distance from the sea of the area from which the eggs were taken. No great success was achieved, however, in the experiments even when eggs from a fairly adjacent spawning area were used.

(d) **Use of landlocked sockeye** *(O. nerka kennerlyi)* **eggs to establish, maintain or increase populations of sea-running sockeye (81).** Experimental plantings produced no returns to the area of liberation, and but few recoveries in the fishery. The extent to which natural escape of kokanee or landlocked sockeye yearlings from lakes can result in returning spawning adults is considered still an open question though opinion against it, based on the origin of kokanee and "residuals", has been presented (207, 208).

(e) **Stream improvement.** No precise data are available. Field observations suggest that maintenance of a certain minimum flow according to the size and character of the stream channel and the elimination of scouring flash floods is desirable. Best production is believed to occur in streams which have lakes at their source, or in spawning areas in outlet rivers of large lakes, from which areas the fry make ascent to the lakes.

(f) **Increasing the production capacity of lakes for young sockeye.** That lakes have a limited capacity for rearing young sockeye has been demonstrated (78) as has also the greater return from the ocean of the larger smolts (85). An increase in size of smolts when predator control was tested was noted (92) but no tests have been made of the practicability of increasing production or sizes of smolts by introducing fertilizing materials into lakes to increase the plankton supplies.

IV. Miscellaneous Studies

During the studies of natural and artificial propagation of sockeye salmon opportunities were presented to acquire information on a number of related problems:

(1) Pond retention of young sockeye salmon (58, 102).
(2) Artificial food rations for pond-reared sockeye (57, 61).
(3) Methods used in artificial spawning (60, 68).
(4) Fry production from eyed-egg plantings (65).

Also, throughout the sockeye investigations, a number of studies related to the life-history, habits, growth rates, etc., were made, as and when pertinent data could be assembled.

(1) Factors which might influence adult sockeye on upriver migration (53).
(2) Age and size components of a spawning run, sex ratios, total numbers, and variations from year to year, time migration and relation to stream temperatures and water levels (5, 54, 55, 62, 67, 186, 187).

APPENDIX II

Research on Pink Salmon *(Oncorhynchus gorbuscha)*

I. Information for Regulation

A. Studies of migration in coastal waters and river estuaries by tagging and marking to determine:

(a) **Routes of travel and seasonal occurrance.** Tagging studies have shown very little coastal movement of pink salmon across the British Columbia-Alaska boundary (196, 197, 198, 219). In the northern and central portions of the British Columbia coast there is very little coastwise migration, the fish appearing to enter the inlets and channels almost directly from the sea. In southern British Columbia areas the coastal migrations are longer, the fish travelling southeastward along the coast and paralleling both the east and west coasts of Vancouver Island. Pink salmon spawning in the Fraser-Puget Sound area and a number of streams tributary to the Strait of Georgia are derived from both these routes (46, 145, 149, 188).

Marking programs (148, 150, 154, 155, 162, 165, 170, 173, 176) have in general confirmed the findings from tag recovery but have indicated appreciable catches in Alaska waters of pinks from Massett Inlet, Queen Charlotte Island (170).

(b) **Degree of exploitation.** Commercial exploitation by seine and gill-net fisheries in the central Johnstone Strait areas is estimated to be around 50 to 60 per cent (137). Elsewhere it is not known with any accuracy.

(c) **Selectivity of fishing gear.** Since examination of escapements shows approximate equality of sexes, the fishing gear is considered to be not strongly selective in respect to sex of fish caught. About 70 per cent of the pink salmon catch is made by seine nets which are presumed to be non-selective for size. Gill-nets may, however, be selective.

(d) **Efficacy of regulations.** Since, as shown earlier, pink salmon catches have maintained a fairly constant average level for many years, present regulations are regarded as effective in maintaining the supply.

B. Sampling of catch to determine population characteristics.

No compilation or analysis of length-frequencies in commercial catches has been published although a considerable number of measurements have been recorded for areas in which fish have been tagged. Average weights of fish in different areas and different weeks of the fishing season are available from the mimeographed fishery statistics reports of the Department of Fisheries. Fraser River pinks are of larger size than other southern B.C. populations (Manzer, ms.). "Odd-year" pinks average heavier than "even-year" fish (107); annual and local variations in weight are also discussed. With no known exceptions pink salmon mature at 2 years and all pinks caught commercially are in their second year of life (165). Sex of fish in samples drawn from commercial catches has been recorded in several recent years but the data await analysis.

C. Spawning escapement studies.

(a) **Time of migration.** The approximate time at which pink salmon enter the streams in the various areas and watersheds is well known. A mass of data for individual streams is available in the "B.C. 16" annual spawning stream inspection reports of the Department of Fisheries. There is little evidence of well-marked separations of "races", on a time-of-run basis, within watersheds.

(b) **Population characteristics.** Size of fish in escapements has been recorded for two areas where field research stations have operated (160 and Hunter unpub.). Significant differences in average size have been shown to exist between different years and between the earlier and later fish in the same year. Sex ratios have been found to be approximately 1:1 in these localities (137, 183).

(c) **Mortality in upriver ascent.** Distances and time periods involved in upriver migration are usually relatively short. No information on mortality due to obstructions, delays, etc., is available. Predation by bears can be significant at times (137).

II. Assessment of Natural Propagation

In order to have (a) a general understanding of the natural production of pink salmon under naturally-varying climatic conditions, (b) some conception of the ranges of variation that can take place, and (c) some basis upon which to evaluate any improvement measures that might be tested, an investigation of the natural production of pink salmon fry from known egg depositions was undertaken. Studies were made first in a highly productive area, Massett Inlet, Graham Island, Queen Charlotte Islands. One stream, McClinton Creek, was selected. Subsequently a few years' tests were made on a small pink salmon stream on the lower east coast of Vancouver Island, Morrison Creek. Later a stream in the central coastal area, Port John (Hooknose Creek) was used. At the same time, observations on pink salmon propagation were carried on, along with studies of chum salmon production, at a small east coast of Vancouver Island stream, Nile Creek, where the pink run had practically ceased to exist. In each of these localities, information was obtained from adult and fry counting weirs and from field observations.

A. Spawning.

(a) **Egg deposition.** Average egg content of females in various years and localities has varied from 1,535 to 1,899, with a general average of 1,700 (88, 137, 160, 183). Correlations between length and weight of females and egg content have been established (89). Presumed egg depositions of natural escapements have been determined for 6 years at McClinton Creek (183), 7 years at Port John (112, 113, 115, and unpub.), and 2 years at Morrison Creek, V.I. (unpub.).

(b) **Sex ratios.** These usually approximate 1:1 on the spawning grounds. It has been suggested (Shepard unpub.) that a reduction in male populations to a 1 male to 2 female ratio might not adversely affect spawning efficiency.

(c) **Effect of water levels.** Stream water levels frequently determine (1) the accessibility of the spawning grounds, (2) the times at which fish are stimulated to enter or ascend the streams, and (3) the area available for spawning (137, 141, 183). Positive correlations have been found (157) for numbers of pinks migrating into the spawning stream each day and both the maximum daily water height of the stream and the daily rainfall in the area. In dry years large numbers of pink salmon are often unable to enter and ascend streams, with potentially serious results. Under conditions of reduced flow fish have been know to die from asphyxiation before spawning (3). High water levels and rapid flow tend to make ascent difficult and may cause spawners to construct redds in gravel bars, etc., which may later become exposed, the eggs then subject to dessication, loss through insufficient water flow or high temperatures or to freezing. An inverse correlation between fry production and October discharge records has been found to occur in one test stream. It is felt that high water conditions in October, when eggs are in a sensitive state, causes considerable loss.

(d) **Effect of prevailing water temperatures.** No relation between water temperatures and time of entrance of pinks into spawning streams has been shown for B.C. streams. This is in accord with data from other areas (45).

(e) **Losses due to predators.** No precise data are available. Losses are believed to be generally light. Cameron (unpub.) suggests that losses due to predation and incomplete spawning may be 10 per cent of egg deposition at McClinton Creek.

(f) **Losses in unspawned females.** Normally very light.

(g) **Losses due to incomplete egg releases.** Normally low—averages for the Port John test area 2.7 per cent in 1951 and 0.96 per cent in 1952 of average egg content per female.

B. Egg incubation.

Periodic examination of pink salmon redds has been done in several test areas but it has been difficult to assign losses to particular factors. For one series of observations (27), non-fertilization amounted to an average of 1.8 per cent of eggs recovered from five redds (range—0.8 per cent to 3.2 percent). From

observations made at McClinton Creek in 1940 the following assignment of losses during spawning and incubation is reported (Cameron unpub.):

Predation on adults and incomplete spawning	—10%	of	eggs	available
Exposed by superimposition	— 5%	"	"	"
Erosion of redd areas	—10%	"	"	"
Incubation and alevinage	—30%	"	"	"

or a total loss of 46 per cent of eggs available for deposition.

C. Fry hatch and migration to sea.

Mortality is believed to be caused largely by populations of predator fishes —trout, young coho, and sculpins (158). Cameron (unpub.) places this loss at 60 per cent; Hunter (unpub.) at from 25 per cent to 75 per cent during a migration—as revealed by recovery of marked fry—or an average of 50 per cent for the whole run. It is recognized that heavy freshets or severe drought could cause serious mortality if occurring during fry migration time. No occasions which could be analyzed have been experienced.

D. Overall percentage fry production from known egg deposition.

Many data are available from a number of different areas (112, 113, 115, 137, 141, 161, 162, 166, 167, 183) and in unpublished Summary Reports. They run as follows:

McClinton Creek, Queen Charlotte Islands, 1930-31 to 1940-41: 10.6, 17.4, 9.0, 6.9, 23.8, 19.0.

Morrison Creek, Vancouver Island, 1943-44 and 1945-46: 4.7, 6.7.

Port John, 1947-48 to 1952-53: 0.88, 8.17, 6.45, 15.12, 16.47, 14.42.

For the McClinton Creek data the variations in mortality during production —76.2 to 93-1 per cent—are believed due (183) to a variety of climatic and environmental causes and also to the variation in spawning population level, for it is shown that with certain limits and under reasonably uniform climatic conditions, there is an inverse correlation between total egg deposition (spawning) and percentage production of fry (137, 182). For Morrison Creek the data are too limited to draw firm conclusions. For Port John, analysis of data is not complete. As mentioned elsewhere above, a negative correlation ($r = .9024$) has been found between October stream discharge and pink salmon fry survival in the following spring. The range of percentage fry production which can occur, as shown by the Port John records, namely, from 0.88 per cent to 16.47 per cent, is of particular interest.

E. Seaward migration of fry.

As noted, also, for sockeye salmon above, much information has been obtained regarding the habits of pink salmon fry during seaward migration, their reaction to light, temperature, water flow, etc. Some of it has been reported (108,174) but there is a great amount of unpublished material in the annual Summary Reports of the Pacific Biological Station.

F. Adult return from the Ocean.

The general strong tendency for pink salmon to return to the streams

where hatched has been confirmed (165) and also, as noted above, their return at an age of two years (165).

The return of adults to test streams from which known fry migrations occurred has given information on the per cent return from the ocean and minimum records of the ocean survival from fry to adult stages, including fishing mortality, the extent of which has not been adequately measured but assumed, as indicated above, to be around 50 to 60 per cent. The recovery of "marked" adults from known fry markings has been found **not** to give reliable quantitative data (165) and therefore the total adult returns to test streams have been used. These are:

McClinton Creek: 0.29, 6.75, 0.42, 1.78, 0.74: geometric mean—1.016%.
Port John : 5.2, 3.1, 3.2, 3.7, 0.71: geometric mean—2.67%.
Morrison Creek : 0.93%.

The factors affecting ocean survival have not been clearly defined. Oceanographic conditions and variations in distribution and intensity of the fishing gear have been suggested (185).

III Studies Directed to Improvement in Natural Production

(a) **Attempts to produce pink salmon runs in "off" years.** In certain areas of British Columbia pink salmon runs occur only in alternative years. In Massett Inlet, Queen Charlotte Islands, where heavy runs occur in the "even" years—1950, 1952, etc.—practically no pinks can be observed in the alternate —the "odd" years. Fo rthe Fraser River, in contrast, large runs occur in the "odd" years—1951, 1953, etc.—and very few pinks are found in the "even" ones. In other B.C. areas there are runs every year, though they may vary greatly in size in "odd" and "even" years. Causes of these peculiarities have been discussed (138).

The factors responsible for this peculiar "on" and "off" year production have not been established but the value of bringing the "off" years into production was early recognized. Experiments were undertaken (163, 164) by transfer of eggs from other areas in the "off" seasons. No success was achieved, perhaps due to the limited number of eggs used in the transfers. Similar tests are being made in the Fraser River and in the State of Washington, using Skeena River pink salmon eggs in the "off" year, but the results have not yet been reported.

(b) **Artificial propagation, with planting of "eyed" and "green" eggs.** See similar section under chum salmon, below.

(c) **Use of planting areas with controlled water flow.** See similar section under chum salmon, on following page.

APPENDIX III

Research on Chum Salmon *(Oncorhynchus keta)*

I. Information for Regulation

A. Studies of migration in coastal waters and river estuaries by taggi and marking to determine:

(a) **Routes of travel and seasonal occurrence.** There is no evidence of lar movements of chum salmon across the British Columbia-Alaska boundary (19 197, 198, 219. In the coastal areas from the Skeena River south to the northe end of Vancouver Island no extensive coastwise migrations are indicated, t fish appearing to move in more or less directly from the ocean to the rive and streams. Chum salmon entering Johnstone Strait from the north distribu themselves along the east coast of Vancouver Island and along the mainla shore as far south as Puget Sound (31, 145, 149, Manzer, unpub.). They al migrate inshore through the Strait of Juan de Fuca but the numbers and the distribution have not been adequately investigated.

(b) **Degree of exploitation.** In the central-Johnstone Strait areas commerci exploitation is estimated to be around 50 per cent (31, 137). For other are no data are available.

(c) **Selectivity of gear.** Since the spawning escapements show approxima equality of males and females, fishing gear is not considered to be strong selective in respect to sex of fish. From 50 to 60 per cent of the fish are caug by seines, which are considered to be non-selective; of the remainder, whic are taken by gill-nets, some size selection may occur.

(d) **Efficacy of regulation.** Regulations are considered to be general effective, since, although wide fluctuations in catches may occur from year year, no general downward trend is apparent (107, 137). Some degree of ove fishing may have taken place in the Vancouver Island region where fishing very intensive and stocks seem to have declined.

B. Sampling of catch to determine population characteristics

Data on size frequencies and age compositions of commercial catches hav been obtained in many areas (32, 107, 172), Robertson unpub., Wickett unpub. Considerable differences in average size of fish caught during different perio of a season and in different years are indicated.

In general, four-year fish contribute from 40 to 90 per cent of the catche the balance consisting mostly of three-year fish but with a small percentage five-year-olds consistently present.

Sex ratio studies indicate that the males and females are quite even represented, in general.

C. Spawning escapement studies.

(a) **Time of runs.** The time of entrance of chum salmon into spawnin streams varies in different areas and may differ noticeably between quit

closely adjacent streams, as indicaed by Fishery Inspectors' reports. Average difference in the times at which runs to various areas in southern B.C. pass through the Johnstone Strait fishery have been found (Manzer unpub.). In general, however, there is no sharp segregation of these "area" runs. In some rivers there is a well-marked early run, usually of small proportions, followed, after an interval of up to several weeks, by the advent of the main body of spawners (137).

(b) **Population characteristics.** At Port John, chum salmon marked as outgoing fry returned in the following proportions: third year, 20 per cent; fourth year, 72 per cent; fifth year, 8 per cent. In many cases age determination by examination of scales is not feasible for fish after they have entered fresh water. Size differences between populations of different streams are strongly suspected but data are insufficient for making sound comparisons. Sex ratios in escapements examined have closely approximated 1:1 (137).

(c) **Mortality during upriver ascent.** Mortality among adults tends to be small since distances are usually short and water levels have usually increased by the time this species enters the streams. In unusually dry seasons mortality of unspawned fish has been observed in small streams on Vancouver Island.

II. Assessment of Natural Propagation

As for pink salmon, noted above, one objective of the chum salmon research has been to study natural propagation in a number of streams. Young chum salmon migrate to sea as fry, shortly after emergence. Hence the study has involved the determination of the number of chum fry produced from a known spawning or egg deposition over a period of years in order to assess the effect of different climatic situations—wet or dry, warm or cold—on fry production. Consideration has also been given to the rate of production according to the extent of the spawning population, i.e. the number of eggs deposited. It is necessary to know what the normal levels of natural production are before attempting to effect practical improvement. Propagation studies have been carried on at Nile Creek and Port John for a number of years.

A. Spawning.

(a) **Egg deposition.** The average egg content of females in various years and localities has been found to vary from 2,254 to 2,943, with a general average of around 2,700 (88,137). The potential egg deposition of a natural escapement has been computed for two test streams—Nile Creek and Hooknose Creek, Port John. At the latter, the presumed egg depositions have varied from 714,500 in 1949 to 10,977,500 in 1947, average for six years—3,023,000.

(b) **Sex ratios on spawning grounds.** Although variation in numbers of males and females occur in all spawning areas, observations indicate that the sex ratios are generally fairly even.

(c) **Effect of stream water conditions.** As a general rule chum salmon tend to frequent the lower stretches of coastal streams and river tributaries, concentrating in such regions with less inclination to distribute themselves

evenly throughout the stream than occurs for other species. There can, therefore, be more overcrowding and more utilization of marginal or questionable gravel areas with greater potential loss in eggs if stream level drops radically.

(d) **Losses in dead unspawned females.** As with pink salmon, observations indicate that in general there is very little loss in females dying unspawned. There are exceptional situations when, due to sudden drought, stream flow drops to such a low level that spawners become trapped and are lost. These occasions are rare.

(e) **Losses due to incomplete egg release.** In general, this loss is low but may, on occasion, be appreciable. For example, at Port John, in 1952, egg retention amounted to only 0.51 per cent. In 1951, however, it was 4.7 per cent.

B. Egg incubation.

Losses during the period of egg incubation for chum salmon (133) are generally similar to those noted above for pinks except that quite frequently there is more wastage due to incomplete covering of eggs in redds or more drifting of eggs out of the redd areas. This loss has not been specifically assessed.

The probable overall loss in chum eggs and alevins during the incubation period is found, from redd sampling, to be generally around 50 to 60 per cent of eggs deposited, although examination of 10 redds in the 1947-48 season indicated a survival of only 13.75 per cent of eggs found therein (112). In 1948-49, extremely cold weather in January and February caused a zero survival in all redds situated near the stream banks where freezing occurred (113).

C. Fry hatch and migration to sea.

Records available from Port John show the following percentages of fry production from known presumed egg depositions under prevailing climatic and stream conditions: 0.99, 7.35, 6.22, 15.09, 16.9, 19.41. The very low 0.99 per cent production was obtained from the relatively very high deposition of close to 11,000,000 eggs. At Nile Creek, natural production of chum salmon fry has varied from 0.08 per cent to 7.0 per cent (221), the very low survivals being due largely to the scouring and shifting of stream bed gravel by exceedingly severe flash freshets 133).

D. Adult return from the ocean as percentage of fry released.

At Port John where only one determination has yet been made, a return of 2.6 per cent of liberated fry resulted. The mortality—97.4 per cent of fry released—includes both natural loss and fishing drain. At Nile Creek adult returns have varied from 0.4 to 1.8 per cent of fry released, again making no correction for fishing mortality, the extent of which is unknown.

III. Studies Directed to Improvement in Natural Production of Pink and Chum Salmon

(a) **Value of artificial propagation.** Studies at Nile Creek (221) suggest that planting of eggs, either "eyed" or "green" may be more successful than

for other species. No research is planned for the near future but rather studies on the improvement of natural production.

(b) **Stream improvement.** The increase in fry production resulting from use of sections of stream where water flow can be controlled is indicated in the section below. Controlled flow and proper preparation of gravel areas to ensure adequate percolation of water will likewise increase spawning and egg incubation but there are no specific data available (141)

(c) **Use of streams with controlled water flow.** Two tests at Nile Creek (221) have indicated an increase in fry emergence of from 1.4 to 13.5 per cent and from 7.2 to 16.8 per cent, respectively.

(d) **Water flow through gravel and gravel composition.** The oxygen supply to salmon eggs has been shown to depend on velocity of water flow and prevailing dissolved oxygen content of the gravel water (222, 223) A study of the hydraulics of salmon spawning beds is now in progress in which the various factors of composition, permeability and hydraulic grade lines, etc., and means of assessing them in the field are being investigated. It has already been found that removal of fine particles (silt) from gravel improves the survival of chum salmon eggs from incubation.

(e) **Predator control.** The value of removing predators from or keeping them out of controlled planting areas has been shown (221) to reduce predation from 50 to 20 per cent. The significance of predator populations in reducing salmon fry populations has been indicated (137), particularly the ratio of abundance of predators to abundance of fry. Port John studies indicate that around 40 per cent of pink and chum fry migrations can be saved if predators can be removed. Large-scale poisoning may be a practical means of reducing numbers of predators, particularly cottids.

APPENDIX IV

Research on Spring and Coho Salmon
(Oncorhynchus tschawytscha and O. kisutch)

I. Information for Regulation

A. Studies of migration in coastal waters and river estuaries by tagging and marking.

(a) **Routes of travel.** Most of the tagging experiments have been conducted on troll-caught fish. Due to the mortalities involved and loss of tags no useful data on the degree of commercial exploitation were obtainable. Intensities and location of the fisheries, both troll and net, so influence the area of tagging and the distribution of recoveries that the taggings reveal largely only the routes of travel along the coast and, in some cases, the river system to which the fish proceed.

SPRING SALMON. In 22 experiments a total of 7678 spring salmon have been tagged off the B.C. coast from 1925 to 1952 of which 930 or 12 per cent have been recovered (35, 128, 146, 153, 224, 225, 228, and Milne, unpub.). Very little difference in percentage recovery of tags between early and more recent taggings is indicated. Off the west coast of Vancouver Island in the period 1925-1927, 12.8 per cent of 3049 tags used were returned, whereas in 1949-51, of 1033 tags put out, 13.3 per cent were recovered. For the Queen Charlotte Islands area in 1929-30, of 1935 spring salmon tagged a recovery of 13.5 per cent was made; in 1951, of 64 springs tagged only 11 per cent were retaken. The majority of the spring salmon travelled long distances down the coast, in a south-easterly direction along the continental shelf to the larger rivers. Many were captured enroute. The Columbia River fish predominated in the early years (1925-1930) but other large rivers such as the Fraser are important in recent years (1949-1952). From taggings off the west coast of Vancouver Island fewer returns were from the Columbia River (16 per cent of the total recoveries compared to 60 per cent) and more from the Fraser River (10 per cent compared to 5 per cent) in the recent experiments than in the earlier ones. In recent years more fish were recaptured near the tagging areas as an indication of the greater intensity of the troll fishery. The result is that 30 per cent of the total recoveries were caught in U.S. waters recently, compared to 82 per cent twenty years ago.

Many of the fish tagged off the north-east coast of Vancouver Island were recovered from the Gulf of Georgia and Puget Sound (45 per cent of the total recoveries). Those tagged in the Gulf of Georgia had a more local distribution with many to the Fraser River and a few to Puget Sound (8 per cent). The recent tagging at Sooke traps resulted in a high return of 22.4 per cent of the fish, mostly from the Fraser River.

As tagging locations moved north, fewer returns were from the south and more were taken in the north. For example, the early taggings off the north-west coast of the Queen Charlotte Islands resulted in 58 per cent of the returns in U.S. waters to the south (26 per cent from Columbia River) and 2 per cent in south-east Alaska. In the small 1951 experiment there were no returns from the Columbia River or south and only 43 per cent from waters off Washington States. Those tagged in Hecate Strait had a more localized distribution in B.C. with 35 per cent returned from United States waters.

In summary, the theory of a north-westward feeding migration of young fish coupled with a south-eastward spawning migration of adults has now been firmly established for spring salmon caught in the outside waters of British Columbia, with the larger rivers dominating in the catches in a north-west direction from their mouths. The only region in which many tags were recovered in the years following the tagging is from the "feeding area" off Barkley Sound, V.I. For inside waters, Hecate and Georgia Straits, the fish appear to move in a more random manner, similar to offshore conditions south of the Columbia River where fish are recaptured both north and south of the tagging areas.

COHO SALMON. In 26 experiments a total of 9326 coho salmon were tagged off B.C. from 1925 to 1951 of which 844 or 9 per cent were recovered (33, 122, 125, 136, 147, 152, 224, 225, 228, Milne unpub.). Comparison of early and more recent taggings shows that for the west coast of Vancouver Island experiments in 1925-27 a recovery of 6.1 per cent of 376 tagged fish resulted whereas in 1950-51, of 1426 fish tagged, 9.2 per cent were retaken. For taggings off the Queen Charlotte Islands in 1929-30, 6.3 per cent of 1828 tagged fish were recovered, while in 1951, 8.0 per cent of 614 tages were returned. For taggings at Sooke traps—157 coho in 1928 and 150 in 1951, the recoveries were 21.0 per cent and 21.8 per cent respectively.

The coho salmon radiated in more directions from the tagging areas and travelled shorter distances than the spring salmon. In general they appeared to move in all directions towards the numerous small streams along the coast which indicates the overlapping of many small populations. All tagged fish were recovered in the same year as tagged.

From the west coast of Vancouver Island the majority of the recoveries were to the east and south, from the Fraser River and Puget Sound, with about 10 per cent from the Washington coast. More were recovered from Puget Sound in the recent experiments than from those conducted 20 years ago.

From the north-east coast of V.I. most of the tagged coho were recovered from Georgia Strait and Fraser River (14 per cent of the total recoveries) with a few from Puget Sound (4 per cent). About 8 per cent of the total recoveries were made north of the tagging area. Approximately one quarter of the fish tagged at Sooke traps were recovered in Puget Sound and the remainder in the Fraser River.

In the Gulf of Georgia the small cohos, called "bluebacks," radiated from the points of tagging in all directions and most probably remained throughout their lives in inside waters. The same indication of restricted movements was evident in various parts of Hecate Strait where the populations of many small coastal streams are involved.

From the north-west coast of the Queen Charlotte Islands the recoveries ranged from Alaska to as far south as Vancouver Island. The recent returns from south-east Alaska were higher (29 per cent) than those recovered 20 years ago (19 per cent).

In summary, the coho salmon migrate shorter distances and in more directions from the point of tagging than spring salmon do. They also travel more slowly, and, as suggested by the greater length of time between tagging and recovery for equivalent distances, appear to wander more during both their feeding and spawning migrations with the result that the populations are more restricted, although fish recovered in the Fraser River have been tagged as far north as the Alaska boundary and as far south as Oregon.

MARKING EXPERIMENTS. The only experiments in B.C. were conducted at Cowichan River, V.I., from 1937 to 1944 when 450,000 spring salmon and

650,000 coho salmon were marked (130, 131, 135, 139). Because no intensive search for ocean returns was made only 65 marked spring salmon were recovered, these taken throughout Georgia Strait and along the west coast of Vancouver Island. For coho salmon, 90 per cent of the 191 ocean returns were caught in Georgia Strait and the remainder off the west coast of Vancouver Island, the fish probably going around both ends of the island. The majority were taken in or near the home tributaries of Cowichan River.

(b) **Fluctuations in abundance.** For the Fraser River and Swiftsure Bank a detailed review of the early troll and net fisheries was made many years ago (217). Seasonal occurrence and changes in abundance of each species were also discussed. For the Skeena River, catches of both species have been studied (Milne ms.). The troll fishery in general is discussed by Milne (126).

(c) **Seasonal and depth occurrence.** Spring salmon catches are made from April to September with peak landings in July. Coho salmon are caught from June to October with peak catches in August. Most of the spring salmon are taken by troll less than 10 miles from shore and at a depth of around 15 fathoms, while coho are caught less that 20 miles from shore and around 5 fathoms in depth.

(d) **Selectivity of fishing gear.** Gill-net selectivity has been studied by the International Pacific Salmon Fisheries Commission. Selectivity of different type and sizes of trolling lures has been studied (Milne unpub.) indicating that spoons catch more fish than plugs and that for spring salmon the larger lures were taken by the larger fish.

(e) **Food studies.** In order to determine what foods are taken in the ocean by spring and coho salmon—these species being more omnivorous species than sockeye, pink and chum—a number of stomach content studies have been made (190, 191, 192, 193, 194, 226, Milne unpub.). They reveal that fish, herring, and sand lance, and pilchard when available, are the main foods, augmented by various types of crustaceans. Coho salmon take a greater variety of food and consume more crustaceans than the spring salmon.

B. Sampling of the catch to determine population characteristics.

SPRING SALMON. Many age readings have been made (100, 103, 104, 126, 128, 169, Milne unpub.). In the earlier years, 1928-30, 90 per cent of the fish were of 4 and 5 years and 78 per cent had gone to sea as fry. In more recent times the fish have been caught at younger ages. For spring salmon caught off Ucluelet in 1949, 84 per cent were in their 3rd year, compared to 28 per cent of this age group in the same area in 1926. Recent studies (Milne unpub.) show that spring salmon caught by trolling range from 2 to 5 years; the majority are in their 3rd year in southern waters, and in their 4th year in more northern areas.

COHO SALMON. Age readings (101, 103, 104, 124, 131, 159, 169 and Milne unpub.) indicate that 95 per cent of the fish are in their 3rd year with 99 per cent going to sea as year-old smolts. Observations at Nile Creek (220) indicate

that some coho proceed to sea as fry, probably not surviving the early transfer to salt water; observation at Cultus Lake (93) indicated that some coho remain in fresh water for 2 years, going to sea in the beginning of their third year and returning that fall.

Growth rate studies showed (124) that coho double their weight in the final summer and that the "blueback" coho, presumably living entirely in "inside" coastal areas, weigh about one half as much as cohoes caught in "outside" areas.

C. Spawning escapement studies.

From Department of Fisheries Inspectors spawning ground reports the general escapement picture appears to be:

SPRING SALMON. Approximately 500,000 fish spawn in the 200 or more streams, about 75 per cent in 15 relatively large systems. The white springs spawn mainly in certain mainland streams. They enter the Fraser River later in the season than the red springs (224, 227).

COHO SALMON. Approximately 3,000,000 fish spawn, the 15 best streams accounting for around 40 per cent. Coho salmon disperse widely and are to be found in almost all coastal streams and tributaries of rivers, even to the most remote creeks.

Observations have been made on only one large river, the Cowichan, (132, 177, 189) with reference to the size of the spawning populations and the characteristics of migration, as related to time, water flow, etc. A diurnal fluctuation in upstream movement was noted (118, 132), greatest movement occurring in the daytime, apparently related to light but not to water temperature, river discharge or tidal influence.

The coho runs at Port John are also under observation, chiefly with reference to propagation (112, 113); similarly those at Nile Creek (220). No reports on migratory characteristics, losses, etc. has, as yet, been prepared.

II. Assessment of Natural Propagation

In view of the fact that spring salmon spawn normally in relatively large streams and in areas of fast water where field observations are difficult and no assessment of natural production can be made, except at great cost, very little information on fresh water survival, etc., has been obtained.

A study has been made of the egg content of female fish and its relation to size of fish (88); there are some records of the analysis of stomach contents of fingerling spring salmon taken in Shuswap Lake (36); examination of scales from spring salmon has shown (136, 169) that the individuals of this species may go to sea during the first year (80 per cent) or as yearlings; reference is made (135) to the effect of higher water temperatures, the result of diminished

river flow and reduced forest cover, in causing the disappearance of an early-running population of spring salmon in the Cowichan River.

For coho salmon, more data have been collected. Since the species normally spawns in coastal streams or tributaries of larger rivers and the young fry spend one year in the stream or river prior to seaward migration, there are, as with the sockeye, two periods at which production can be assessed, namely the fry and the smolt stages.

A series of records for fry survival in two streams tributary to the Cowichan River, Vancouver Island, 1938-1945 (135) from known egg depositions gave a range of from 11.8 to 40.0 per cent for 12 determinations and an average of 22.8 per cent. This average efficiency, high in comparison with similar data for pink and chum salmon fry production, is thought to result partly from the more stable condition of stream flow and bottom materials and less crowding of redds. Variations in production are considered to be due partly to predator activities and partly to prevailing water level conditions. The fry move down into the Cowichan River and remain there for a year during which time they are subject to loss from predators, unfavourable summer water flow and water temperature conditions, etc. A close correlation was found between the summer water levels of the Cowichan River and availability (abundance) of returning adults (135).

At two test areas, Nile Creek and Port John, young coho proceed to the sea both as fry and as yearlings. At Nile Creek (220) the fry are believed to drop down into the intertidal zone where, on the basis of tests made, the majority probably die. For both test areas the yearling production, based on eggs deposited, is relatively low (113, 220) ranging from 0.7 to 2.1 per cent. In a quite different habitat where the coho spawn in tributaries to a lake and the young fish remain in the lake for a year (93), although a small fry migration does occur, production of seaward migrants is very low, 0.13 per cent of eggs in spawners. It is indicated that most of the coho fail to migrate, remaining in the lake into their second or third year.

Records from Nile Creek and Port John reveal that a relatively good return of adults from smolt migrations may occur. Nile Creek data show a return of 3.2, 4.9 and 9.9. per cent of yearlings released (220) while the Port John records are: 7.0, 7.2, 3.8, and 19.1 per cent of smolts released. A return to Cultus Lake (93) of marked coho showed an ocean survival of 8.1 per cent.

In addition to the above investigations of the natural production of fry and yearlings, studies have been made of

(a) the egg content per female in relation to size (88) and average egg content in samples from test streams (113, 220),

(b) seaward migrations, with particular reference to numbers, size, age, etc. (56, 84),

(c) coho salmon as predators of young sockeye.

APPENDIX V

Studies to Devise Useful Prediction Indices

At the present time the only measure of the likely abundance of any species of salmon coming in from the ocean to a river system or coastal area is the extent of the spawning in the previous cycle year, as reported by Department of Fisheries Inspectors annually after careful observation of the spawning areas. This measure can be and frequently is quite misleading since climatic and stream conditions can cause wide fluctuations in the efficiency of production.

For sockeye it has been found, on the Skeena River (16), that a statistically significant relation exists, for the years 1920 to 1934, between August and September precipitation and the size of the commercial catches, with amount of seeding held constant. It has been shown, also, that percentage return from the ocean is affected by the size of seaward migrants (85) which, in turn, is related to the number of young sockeye reared in a lake with a limited rearing capacity.

For pink and chum salmon correlations have been found between stream level or discharge at or soon after spawning and the date of the subsequent populations (137). For Port John (Hunter unpub.) a negative correlation has been found between stream discharge in October and pink salmon survival in the following spring. For central coast area pink salmon populations multiple correlations calculations indicate (Wickett ms.) that rainfall and number of spawners together account for 60 per cent of the variation in the stocks during the last 26 years. Vancouver Island chum salmon stocks varied with the brood year November stream discharges. Heavy floods were associated with marked decline in subsequent cycle years (141).

For coho salmon, a close correlation was found between summer water levels and the size of subsequent stocks of fish .(135, 124).

In view of the questionable nature of spawning escapement estimates as a measure of subsequent cycle production, consideration has been given to using estimates of seaward migrations as a better gauge. In this case no highly-fluctuating fresh water mortalities are involved and only the varying ocean mortalities, thus far assumed to be relatively stable, are of concern. For example, a good correlation has been established between the output of pink and chum salmon fry migrants from a particular stream (Hooknose Creek, Port John) and the subsequent return of adults to the same stream (Fisheries Research Board of Canada, Annual Report for 1952, pp. 90-92).

Tests of the feasibility of such procedure for larger areas are being made for sockeye (232) and pink salmon (142). They involve means of obtaining a reliable index of numbers of seaward migrants and methods of sampling for population estimates are being tested. In addition, a system of setting up certain "key" streams in each Inspector's area for frequent observation and report was devised. Suitable report forms were prepared, field apparatus for sampling redds, recording stream levels and temperatures, were obtained. No assessment of the success of the project has yet been made.

APPENDIX VI

General Studies to Increase Understanding

(a) **The relation of physical aspects of environment to various stages of salmon development.** The lethal limits and preferred levels of temperature have been established for all five species of Pacific Salmon (18). The ultimate upper lethal temperatures for each species were: spring—25.1°C., coho—25.0°C., sockeye—24.4°C., pink—23.9°C., chum—23.8°C. The lower lethal temperatures for highest acclimation, 23°C., were: spring—7.4°C., coho—6.4°C., sockeye—6.7°C., chum—7.3°C. Comparatively little difference in preferred temperature was recorded experimentally, either between species or for differences in acclimation amounting to 15°C. in some cases. The region of greatest preference lay in the 12° to 14° stratum.

Maximum sustained swimming speeds of yearling coho have been determined (data on file) at temperatures ranging from 1°C. to 20°C. and similar tests on four species at the fry stage have been begun.

The critical level at which oxygen concentration becomes lethal to chum salmon eggs has been found to be approximately 2.0 p.p.m. at 5°C.

Tolerance of sockeye fry to varying levels of salinity is being investigated.

Responses of coho and chum salmon fry to current (119) indicate a positive reaction to changes in water flow by swimming against the current. Magnitude of response varies with intensity of current, currents giving optimum response differing for the two species.

Behaviour patterns of young sockeye, chum and coho are compared (109). Sockeye and chum fry are schooling fish responding positively to current and avoiding shallow water. Chums, however, form more active schools and have a less marked cover reaction. Sockeye smolts, in contrast to coho smolts, are more active, show little thigmotactic and territorial behaviour and a more persistent response to current. Experimental findings are discussed in relation to the migratory behaviour.

Rheotactic response of chum fry, sockeye fry and smolts and coho fry and smolts have been studied under varying temperature conditions (116). Rheotaxis is predominantly positive at lower temperatures but frequently becomes actively negative at higher temperatures. A positive response was usual at temperatures normally prevailing during seaward migration.

The effect of some hormones on behaviour of salmon fry have also been tested (110). Chum and coho fry, when immersed in solutions of methyl testerone, synthetic thyroxine and thiourea show no new behaviour pattern. Chum fry exhibit quantitative changes in swimming rate and intensity of schooling.

A study has been made of the changes in body chloride, density and water

content of chum and coho salmon fry when transferred from fresh to salt water (12). Both species tolerated 50 per cent sea water. Chum fry survived direct transfer from fresh to sea water with a marked increase in body chloride during the first 12 hours followed by a return to normal between 12 and 24 hours; coho fry, however, died within the first 36 hours, after a 60 per cent increase in chloride. When returned to fresh water after 12 hours in sea water, the body chloride, density and water content of both species regained normal levels within 10 hours.

(b) **Inter-specific cross breeding.** Experiments have been conducted involving reciprocal crosses of all species (66). In one case—chum male and coho female, no fertilization occurred and in several tests, particularly those involving the coho, male or female, and the spring female, most of the embryos died either during development or at hatch. Reciprocal crosses of sockeye, chum and pink and of spring males with other species produced positive results. Male hybrids of the following crosses matured in their third year and their fertility was tested on normal sockeye eggs: (in each case the male parent of the original cross is the first noted) chum sockeye, sockeye chum, pink spring, spring sockeye, spring pink, chum pink, sockeye pink, coho spring. Excellent hatches resulted in all cases. Both male and female hybrids matured in their fourth year but tests with normal sockeye could not be made because of the earliness of the season. The hybrids were therefore interspawned. Sockeye, chum and pink appeared to cross most readily. Hunter (114) discusses the recovery of apparent hybrids of a pink-chum cross breeding at Port John.

(c) **Reproductive behaviour and sexual development.** Histological studies of chum salmon gonads (144) produce evidence of the presence of specialized tissue in the testes at spawning time. Bioassay established the presence of androgenic substance, probably testosterone, about equal in amount to that found in mammalian testes.

Some study has also been made (Milne, unpub.) of the development of secondary sexual characters as salmon mature, particularly with reference to increase in snout length and in depth of body.

(d) **Factors influencing upstream migration of salmon.** A number of field observations have been made in an attempt to indicate the influence of physical factors such as temperature, stream flow, etc. For sockeye, from studies made at the junction of a tributary sockeye stream and the Fraser River (53), no obvious differences in temperature, pH or dissolved oxygen content which might be guiding influences were found. Tests of releasing tagged adults below a counting weir indicated (214) that though the fish might drop downstream and proceed some distance up a neighbouring one, they, in due course, return to the original. For pinks, volumes of stream discharge, particularly freshets, have a migration-stimulus effect (45, 157). A similar relation holds for coho salmon but in addition there is found to be diurnal variation (132) related to light intensity; and the run may appear in two distinct periods, early and late (177) even though bound for a single tributary spawning creek.

(c) **Studies on identification of species, variations in meristic characters, etc.** During the course of the salmon researches some miscellaneous studies were made on the identification of the species, as adults (37), as young (90); counts of gill rakers and pyloric caecae in pink salmon (178) were also obtained.

(f) **Salmon in the ocean.** Aside from information obtained in the course of tagging operations, little study has been given to the development of salmon during ocean residence or to the reaction of salmon to oceanagraphic conditions. Data on troll-caught spring salmon (Milne, unpub.) show that all female fish over thirty inches total length or ten pounds in weight are maturing fish, according to egg diameter measurements. Males mature, however, at all sizes.

Some preliminary studies have been made on young salmon found in Departure Bay area (977). The occurence of a heavy mortality of salmon in Cowichan Bay was investigated (94), the situation being found due to unusual oceanagraphic conditions, particularly oxygen supersaturation of the water, affecting the respiratory processes of the fish. Similar situations were found to develop for short periods in occasional years at the Sooke salmon traps during or immediately following periods of hot, calm weather.

APPENDIX VII

Studies of the Effect on Salmon Production of Industrial Projects and the Development of Methods for Eliminating or Ameliorating any Adverse Conditions.

(a) **Guiding salmon during upstream ascent or downstream migration to avoid the adverse conditions produced by hydroelectric power dam installation, water impoundments, diversion canals, etc.** Preliminary studies only have been completed. They have centred on three species at three locations: (1) deflecting migrating young spring salmon in a canal (23), (2) deflecting young sockeye in a large trough and (3) inhibiting the run of adult coho and spring salmon at a falls by the use of obnoxious odors (1, 21, 24).

Experimental success in guiding young salmon by the appropriate use of lights or the use of strands of chain hung vertically 2 to 4 inches apart in the path of the migrants shows promise. The general problems created by high dam installations have been reviewed (19, 83).

(b) **Correcting pollution problems.** Construction of a pulp mill in an important salmon area, Alberni Canal, introduced the problem of the effect on the salmon runs of polluting effluents. The company involved sought scientific advice prior to installation and as a result (218) erected a Kraft mill which, it was recommended, would cause no deleterious pollution under normal conditions of river flow, etc.

APPENDIX VIII

Proposed Research Programs for Salmon

Sockeye Salmon

(1) it is proposed to continue the present studies on the natural production of sockeye in fresh water with particular reference to the relation of environmental factors to survival in order that (a) the factors limiting survival may be made known and the feasibility of taking corrective action assessed and (b) the probable effect of man-made changes in environment, such as removal of forest cover, construction of hydro-electric power dams, construction of water impoundments, agricultural development of land, introduction of irrigation projects, etc., may be ascertained and these changes made as innocuous as possible.

Special study is to be given to the lake-residence stage of the life-cycle to determine the relation of the young sockeye to limnological conditions and to the existing populations of other lake fishes, with special reference to what factors cause wide fluctuations in production and how these may be remedied.

(2) It is proposed to continue—at Babine Lake—the study of the production of smolts from different levels of adult spawning populations to ascertain what might be considered an optimum spawning escapement.

(3) Consideration will be given to the factors governing age at maturity and return from the ocean. Five year sockeye weigh, on the average, from one-third to one-half more than four year fish (Skeena River, 6.5 lbs. :4.9 lbs; Rivers Inlet, 6.9:4.4). It is recognized, however, that mortality occurs during the extra year's residence in the sea. Does the increased weight gained during the extra year compensate for the extra mortality occurring? Is the age at maturity a hereditary character, subject to control by breeding, or is it due to conditions for growth in the sea?

In some years large numbers of precociously-developed males appear, of small size, which are not exploited by the gill-net gear. An explanation for this early maturity is required, also some understanding of the general effect on the sex ratios of the commercial catches and of the escapements in the year or years.

Pink and Chum Salmon

While continuing most of the existing phases of investigation, it is intended to pay increased attention to the following points:

(1) Physical characteristics of spawning grounds. The objective is to establish specifications for stability, gravel size, porosity, oxygen requirements, etc., for construction of new beds or diagnosis of suitability of existing ones.

(2) Determination of the optimum size of escapements, in relation to area and other characteristics of available spawning grounds. This will entail a study of the results obtained from spawning populations of varying density—

to contribute to the answering of the all-important question: What is a proper escapement?

(3) Tests on the feasibility of establishing "off-year" runs of pink salmon in waters which currently produce fish only in alternate years. Despite lack of success in certain former attempts, it is felt that with additional information now at hand, and in view of the possible considerable benefits that might accrue further experiments should be made. A start is anticipated this year.

Spring and Coho Salmon

(1) It is recognized that more information is required on the fresh water phases of the life history, particularly with reference to natural propagation and factors limiting production. For spring salmon, no plans for immediate investigation in fresh water have been made but for coho pertinent information is being collected at Port John and Lakelse Lake field stations.

(2) Growth-rate and food studies will be continued to ascertain the relation of general climatic and oceanographic conditions to the growth and well-being of the fishing during ocean residence. Food preferences will be determined to define the relationships to herring and other fodder fish; also to indicate the relation of depth distribution of the troll-caught fish to preferred food.

(3) Gonad development studies will be continued with a view to assessing, in the troll fishery, the proportion of immature fish caught, areas of abundance of immature individuals, i.e., feeding areas, etc.

(4) In view of the importance of tagging programs in tracing migratory routes and in estimating population size, it is proposed to study various methods of capturing fish for tagging in order to discover which type of gear causes the least mortality after the fish have been tagged and released. Experiments are also proposed to test different types of tags and techniques of tagging to determine the influence of these on tagging mortality and on the extent of loss of tags.

Pacific Salmon—All Species

A. Plans are being formulated to expand the study of the sea life of the various species of salmon, particularly the adult period when the fish are returning from the ocean and passing through the coastal and river estuary fisheries. It is desired to know, firstly, to what extent the fishery exploits the incoming populations of salmon and, secondly, in what manner and to what extent the various forms of fishing gear have a selective effect upon the populations, in respect to sizes, sexes, time of migration, etc. A start will be made in the Skeena River area in 1955.

Sampling of the commercial catches will be continued. Since these samples, mostly taken from the gill-net fishery, may be of a selective nature an attempt will be made also to obtain a sample of the spawning escapement for comparison. By amalgamating the samples a general understanding of the character of the general population may be secured, so far as length and weight distributions, sex ratios, and age compositions are concerned.

B. A laboratory for experimental biology has been equipped to study the effects of temperature, salinity, oxygen concentration and light on the tolerance, preference and activity of salmon (and other commercially important fishes) in the egg, fry, fingerling and adult stages. Studies to determine the relation of the physical aspects of the environment to the various stages of salmon development have been begun and will be continued.

C. Factors influencing the upstream ascent and downstream migration of salmon are presently under study (see Appendix VII,a), with particular reference to guiding them along certain paths or repelling them from others. The use of hanging chains has been found promising and further experiments are in progress. Other devices will be investigated.

D. The development of suitable prediction indices to arrive at a reasonably accurate estimate of returning adult salmon will be further investigated. These will involve (a) the use of seaward migrant estimates as a measure of population and (b) the relation of meteorological records for autumn and winter brood year seasons to estimates of adult return (commercial catches or catch plus escapement).

APPENDIX IX

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OCEANOGRAPHY ALONG THE CANADIAN PACIFIC COAST

by

J. P. TULLY

Pacific Oceanographic Group
Fisheries Research Board of Canada

A REVIEW OF EXISTING KNOWLEDGE WITH AN OUTLINE OF CURRENT RESEARCHES CONDUCTED BY THE PACIFIC OCEANOGRAPHIC GROUP OF THE FISHERIES RESEARCH BOARD OF CANADA.

F R B No. 410

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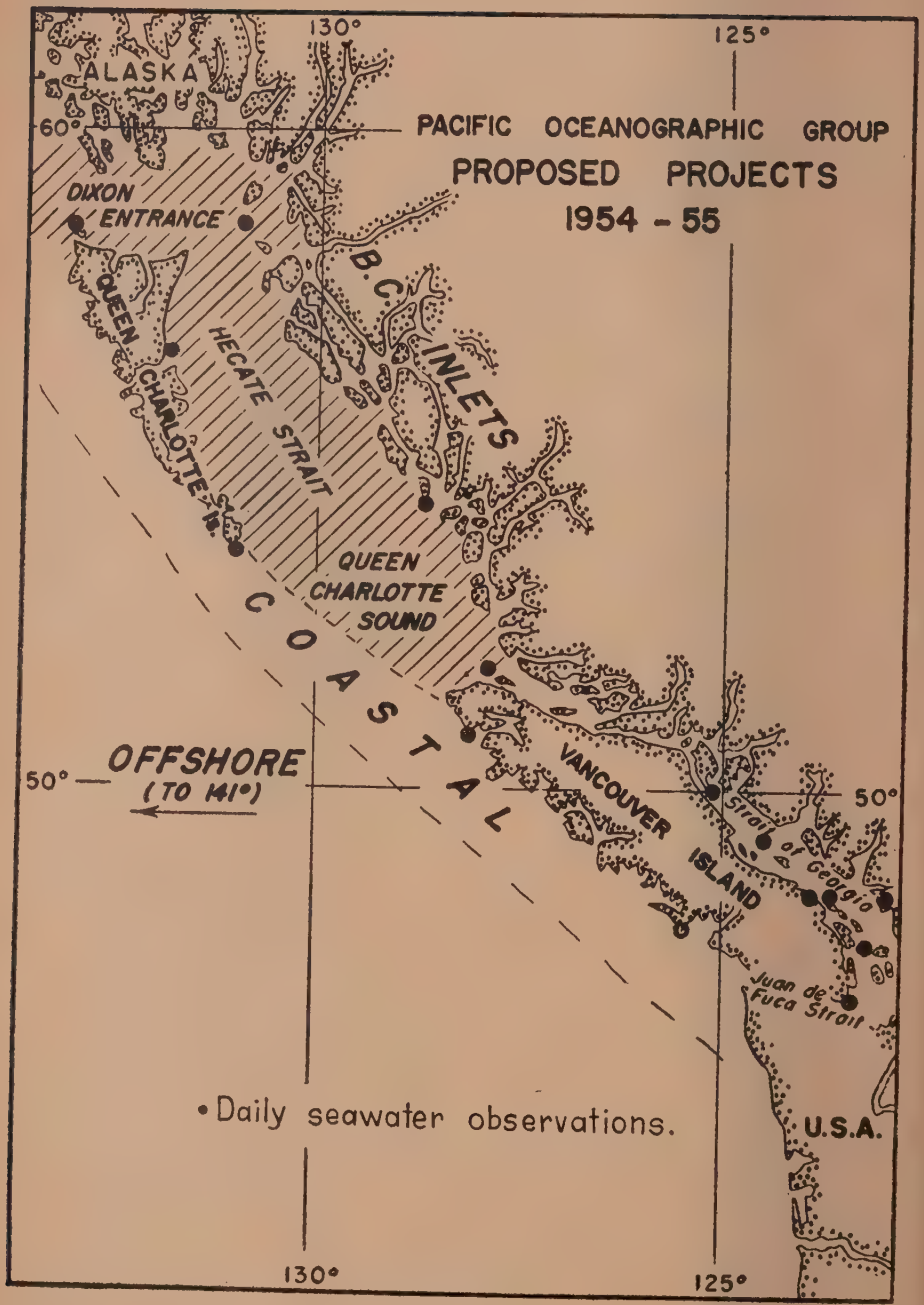
130°
125°
ALASKA
60°
PACIFIC OCEANOGRAPHIC GROUP
PROPOSED PROJECTS
1954 - 55
DIXON ENTRANCE
QUEEN CHARLOTTE IS.
HECATE STRAIT
B.C. INLETS
QUEEN CHARLOTTE SOUND
COASTAL
OFFSHORE
(TO 141°)
50°
VANCOUVER ISLAND
Strait of Georgia
Juan de Fuca Strait
U.S.A.
• Daily seawater observations.
130°
125°

OCEANOGRAPHY ALONG THE CANADIAN PACIFIC COAST

By J. P. TULLY

Pacific Biological Station, Nanaimo, B. C.

Oceanographic studies have been made in many parts of the region shown in the figure. This is divided into natural areas (offshore, coastal, a strait, or an inlet and only one area is studied at a time. Each study consists of oceanographic surveys in successive months or seasons (spring, summer, autumn, winter) through one or more years. In each survey an attempt is made to observe the temperature, salinity, and sometimes dissolved oxygen, at a series of depths from surface to bottom, at a grid of stations covering the area being studied. Every attempt is made to complete the survey quickly so that it may be as nearly synoptic as possible. The data from each study are compiled in a multilithed Data Record which is usually a restricted publication. This Data Record shows the position, depth, and conditions of each observation, the properties observed, and derived quantities such as density, dynamic height, etc.

Daily observations of sea water temperature and salinity at one yard depth are made at fourteen positions (Figure) along the coast. These data extend over various periods from 1914 to the present. Five of the stations are on the ocean coast and data are generally available from 1933 to the present. These data are published annually. They provided continuous definition of the oceanographic conditions.

These survey and daily observation programs are integrated in the study of the data. The surveys show the oceangraphic conditions over the whole area at one time, while the daily observations indicate the duration of such conditions, and the seasonal cycles of water properties.

The studies are published in Manuscript Reports (multilith) of the Pacific Oceanographic Group, Progress Reports of the Pacific Coast Stations of the Fisheries Research Board of Canada. Occasionally publication of methods or theory (not listed here) is made in other journals. Reprints of most of these papers are available.

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Tides

The tidal rise is 10 to 12 feet near Juan de Fuca Strait and generally increases northward to about 22 feet in Dixon Entrance. The tidal currents along the ocean coast and Queen Charlotte Sound are strong (one knot or more) and rotary. In the inlets and large straits the tides are reversing and generally of the order of 2 to 3 knots. In the many narrows velocities frequently reach five or more knots, and at Seymour Narrows, velocities in excess of 13 knots are recorded. In all these passages the flow is turbulent and the waters are mixed to homogeneity from surface to bottom.

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Offshore

The first offshore oceanographic survey was made in July and August, 1936. It included the area within 100 miles of the coast of Vancouver Island. These observations have only been reported partially.

In 1950 to 1952 a series of five oceanographic surveys was made covering the area off the Canadian coast westward to Longitude 141°W., in August, October, November 1950 (frustrated by weather), May 1951, August 1951, and March 1952. These data showed that there was an upper zone, 100 to 150 meters deep, in which all seasonal variation occurred. Below this is a deep zone extending to at least 1,000 meters depth, which is independent of local weather. The upper zone is fresher than the deep zone and separated from it by a notable halocline. In winter the upper zone is the colder and in summer it is the warmer of the two zones.

The calculated currents indicate that the movement in the area is small and indeterminate. Evidently the West-Wind Drift Current crosses the ocean between Latitudes 46 and 51°N. About 600 to 800 miles off shore it divides, part turning south to form the California Current, and part turning north to form the Alaska Gyral. The area off the Canadian coast is one of confused eddies between these major currents in the upper zone.

It appears evident that the latitude of the division of the West-Wind Current may vary from year to year, thus altering the character of the water in this region. In 1950 and 1951 it appears that the division was about Latitude 48°N, and the general trend of movement in this area was northward. However, the 1936 data indicates that the division was further north because the general movement was southward.

Considerable study will be required to solve this system and predict its behaviour. The task was originally undertaken to assess the boundary of the coastal waters. This end has been served.

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In general, there is a strong northward coastal current, within five miles of shore. This current is strongest during the winter (southwest winds) and weakest during the summer (northwest winds). Near the shore the water is cold, 10°—11°C in summer and becomes warmer to seaward, reaching 15° to 18°C about 60 miles offshore. In winter the coastal temperature is only slightly less (8°—10°C) but the water becomes colder to seaward reaching 5° to 6°C about 60 miles offshore. In general, the coastal waters are freshest in winter coincident with the maximum coastal drainage.

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Sound, Alberni Inlet, and Bute Inlet. More general observations and cursory descriptions have been made of many other inshore areas and inlets.

In all these seaways the fresh water from land drainage moves persistently seaward entraining ocean water from below to form a brackish upper zone which becomes more saline to seaward. Below this layer, and separated from it by a notable halocline is the deep zone of ocean water which moves persistently towards the sources of fresh water. The salinity and temperature of the upper zone vary with the season, while the properties of the lower zones are very nearly constant.

This structure is destroyed by the turbulence in the many passes and narrows around the coast where the tidal currents are rapid and violent.

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Seasonal Cycles

The discharge of the large rivers, particularly along the mainland coast, is greatest in May and June, when the snow melts in the mountains. The discharge of the small rivers on Vancouver, Queen Charlotte and other coastal islands is greatest in the winter, coincident with the maximum coastal precipitation. Thus the influence of the big rivers is greatest in summer, while the influence of the small rivers is maximum in the winter.

Temperature is almost entirely due to local insolation. The temperature of the upper zone water increases from March to mid-September, while the air is warmer than the water. From then until March the temperatures decrease while the air is the colder. The greatest range of water temperatures occurs in sheltered harbours and bays. The temperature range of the large straits such as Georgia Strait is intermediate between the bays and the ocean. The most constant temperatures occur in the passes and narrows where the waters are continually mixed to homogeneity.

Although the average cycle of temperatures agrees closely with the seasonal cycle, the daily variations are local phenomena depending on the structure, currents, and mechanism of the waters.

There is evidence to show that the annual average water temperatures increased from 1917 to 1948 and then decreased to the present time.

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Bering Sea

In the summer of 1949 a joint Canadian—United States oceanographic survey was undertaken in the Bering Sea. In general, a northward flow of land drainage waters along the Alaska shore was observed. Further to westward the waters from the Pacific intrude through the Aleutian Island chain and turn westward, returning southward into the Pacific along the Asiatic shore. These waters occupy the upper 100 to 200 meters. Below them is a region of cold saline water, part of which originates in the winter chilled water in the vicinity of the ice fields.

Further north, near the Bering Strait the shallow water occurs in homogeneous masses, clearly defined by haloclines and thermoclines. Most of the boundaries are vertical and are indicated at the surface by tide rips (convergences).

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Present Operations

An intensive study of the oceanography of Queen Charlotte Sound, Hecate Strait, and Dixon Entrance is being undertaken. This includes observations of the physical and chemical properties of the water and the currents.

THE PACIFIC HERRING (*Clupea pallasi*) ALONG THE PACIFIC COAST OF CANADA

by

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Fisheries Research Board of Canada

A SUMMARY OF THE EXPLOITATION AND REGULATORY MEASURES AND A REVIEW OF THE RESEARCH UNDERTAKEN AND PROPOSED.

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THE PACIFIC HERRING *(Clupea pallasi)* ALONG THE PACIFIC COAST OF CANADA

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I. History and Development of the Fishery

The following brief review of the history and development of the herring fishery in British Columbia waters is based largely on the detailed accounts given by Tester *(88, 108, 114[1])*, with material added to bring the account up to date.

Herring have been fished in British Columbia waters since 1877. In that year a catch of about 75 tons was made. In 1953-54 the total catch was about 211,000 tons. Fig. 1 shows the annual catch, with the contributions made by the various sub-districts (see map) from 1910-11 onwards. Catches prior to 1910 are not shown for the records are unreliable. The figures are compiled from data given in the Annual Reports of the Fisheries Branch of the Department of Marine and Fisheries, Fisheries Statistics of Canada and British Columbia Catch Statistics issued by the Federal Department of Fisheries. Records from 1910 to 1916 represent the fiscal year, which includes an entire herring season (October to February), records from 1917 to 1932 are for the calendar year, while those for 1933-34 onwards are for the herring season. The error introduced in using the calendar year is not great, as the major part of the fishery had taken place by the end of December. Apart from the annual fluctuations in total catch eight periods may be recognized in the development of the fishery:

(1) From 1877 to 1900 the catch increased slowly from about 75 tons to 500 tons.

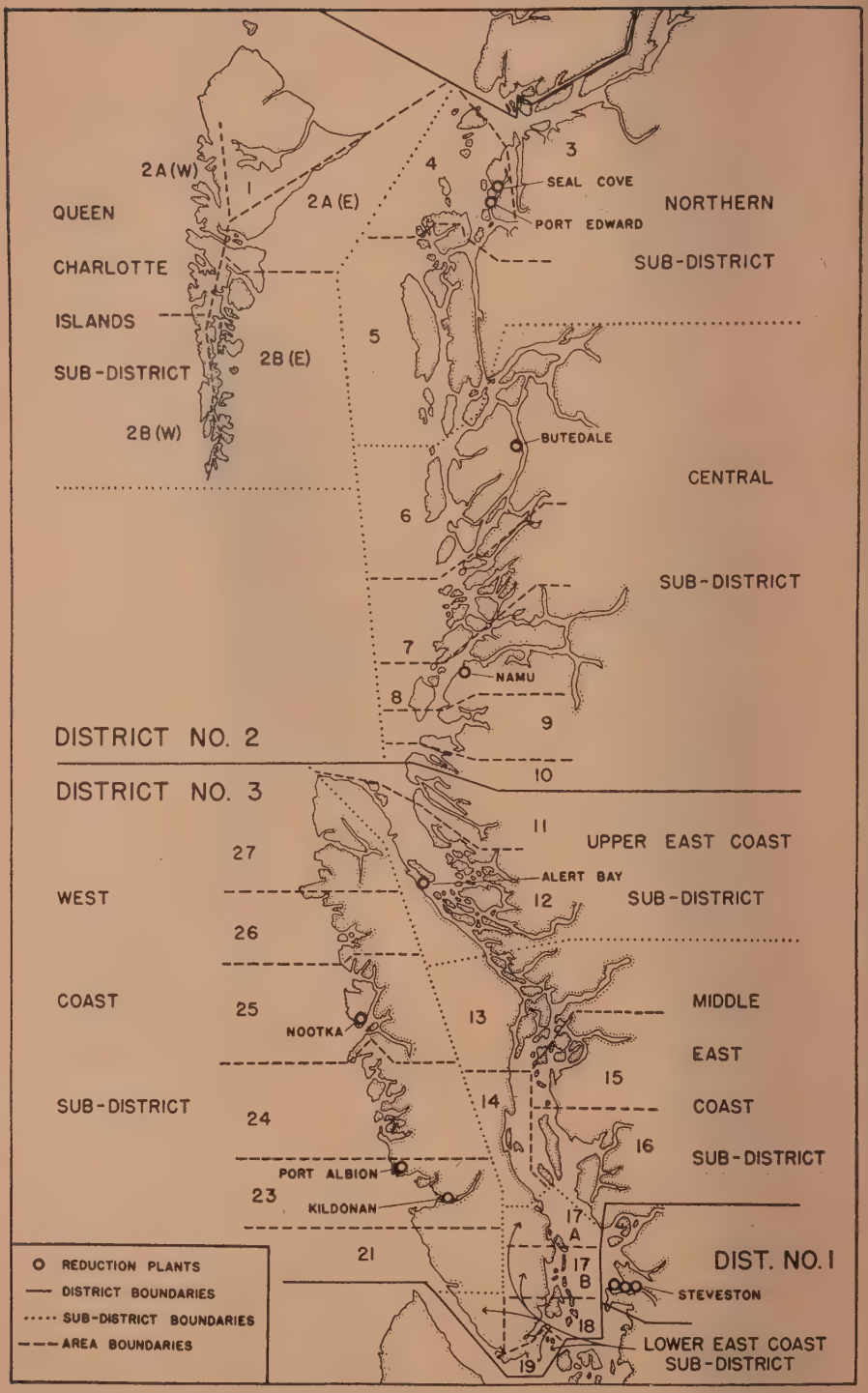
(2) From 1900 to 1909 the annual catch increased to about 30,000 tons. The opening of an oriental market for dry-salted herring in 1904 was largely responsible for this increase.

(3) From 1909 to 1919 the catch varied between 15,000 and 35,000 tons a year, with an average catch of about 20,000 tons. During the First World War the dry-salt industry declined but canning increased to meet war needs. Prior to 1911, fishing operations were mainly confined to the lower east coast of Vancouver Island. In 1911-12 commercial fishing took place for the first time in Barkley Sound on the west coast of Vancouver Island.

(4) From 1919 to 1927 the catch rose from 30,000 to 85,000 tons as a result of the great expansion of the dry-salt industry to satisfy the oriental market. The canning of herring decreased during this period. In 1926-27 fishing was expanded on the west coast of Vancouver Island to the areas northwest of Barkley Sound.

(5) From 1927 to 1934-35 the annual catch dropped from 85,000 tons to 30,000 tons, due to the loss of the market for dry-salt herring.

[1] A bibliography of publications by the Fisheries Research Board of Canada on herring is given at the end of this report. References are given by italicized numbers in parentheses throughout the text or at the end of sections.



Map showing the division of the British Columbia Coast into districts, sub-districts, and areas.

(6) In the period from 1934-35 to 1936-37 the annual catch increased to about 100,000 tons as a result of the development of the reduction industry first established in 1924. The development of the reduction industry was accompanied by the expansion of large scale herring fishing to include waters in the northern (in 1933-34) and in the central (in 1936-37) sub-districts. A small fishery had taken place in waters of northern British Columbia from the earliest years of the fishery; as the catches probably averaged less than 1,000 tons, they are not shown in Fig. 1.

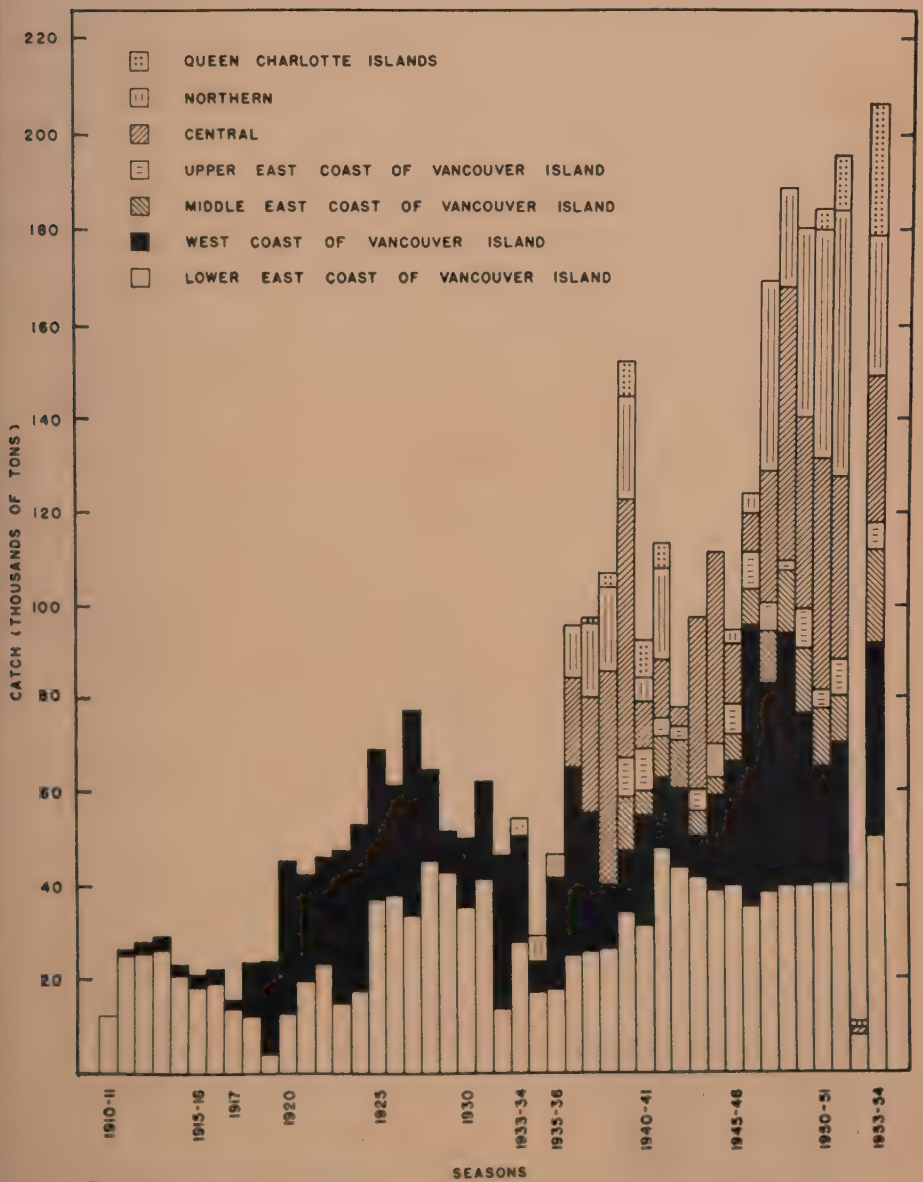


FIGURE 1. British Columbia herring catches by sub-district from 1910 to 1954.

(7) Between 1936-37 and 1945-46 the annual catch fluctuated around 110,000 tons. The greater-than-average catch of 1939-40 resulted from high catches in the northern and central sub-districts, while the below-average catch of 1942-43 was the result of poor catches in these same sub-districts. Market conditions were good particularly in the latter part of the period both for oil and meal and for canned herring. In 1938-39 the Queen Charlotte Islands sub-district was first fished and in 1939-40 the upper east coast and middle east coast (Discovery Passage) sub-districts.

(8) From 1945-46 to 1948-49 the catch increased to about 185,000 tons and has remained at that level until the present. The greatly increased catches have resulted from the intensive exploitation of all British Columbia herring stocks, in particular those in the northern and central sub-districts. The development of more efficient fishing methods also contributed to this increase. It is now virtually certain that no unexploited stocks of any size remain in British Columbia waters. The increase in catch on the west coast in 1946-47 was the result of the removal of quota restrictions. In 1952-53 the almost complete lack of a fishery is explained by the failure of the fishermen's union and companies to agree on the price to be paid. A minor fishery, chiefly for bait and dry-salt herring was permitted.

2. Regulations Governing the Fishery

Reviewed briefly below are the more important regulations governing the herring fishery.

A. Gear Restrictions

Up to 1905 the fishery was carried out almost exclusively by drag or beach seines. These nets were 10 to 30 fathoms long and 2 to 5 fathoms deep.

By 1905 drift gill-nets had come into use at Point Grey near Vancouver and at Departure Bay and Nanaimo Harbour on the east coast of Vancouver Island. These nets, made up of units each 20 fathoms long and 3 to 4 fathoms deep, were set in strings up to half a mile long. They permitted fishing in deeper water than beach seines. The drift nets were made of cotton with a stretched mesh size of 2 to 2½ inches.

Purse seines did not come into use until 1910. A controversy arose over their supposed destruction of small fish and it was not until 1913 that their use was finally permitted. For many years the mesh size has been fixed at not less than 1½ inches stretched measure. Over the years there has been a tendency to allow the use of longer and deeper nets, at present nets up to 275 fathoms in length may be used. For some years prior to 1941-42 "double" or "twin" seines operated from two boats working together were used by fishermen of Japanese origin. Since the 1942-43 season when Japanese fishermen were excluded from the herring fishery as a wartime precaution, only single seines have been employed.

B. Area Restrictions

Certain small areas are closed to commercial fishing either to prevent the disturbance of local sport or commercial troll fisheries for salmon or to protect

certain local herring populations used extensively as a source of bait or for food by natives. In general such closures are not important in limiting the total catch of a statistical area.

C. Time Restrictions

A closed season has been in effect for many years to protect the herring during spawning time. The opening date has varied over the years from May 1 to September 30 and in general has had little effect on the fishery which usually does not develop until at least October. For many years a closure date of February 5 has been maintained for district 3 (see map). In district 2 prior to 1942, when a closing date of March 10 was set, fishing was closed on reports that herring were ready to spawn or when it was judged further fishing might endanger the run. Time extensions beyond the closing date have occasionally been granted. The Chief Supervisor of Fisheries reserves the right to close areas at any time for the purpose of conservation. There has also been in force for many years a weekly closed period from 12 o'clock noon Saturday to 12 o'clock noon on Sunday in districts 1 and 3. This was extended to district 2 in 1941-42. In 1950-51 it was changed in all areas from 12 o'clock noon on Friday to 12 o'clock noon on Sunday. This weekly closed period has no special conservational purpose but allows the fishermen a period for rest and net repair.

D. Quotas

In 1936-37 catch quotas were established for fishing grounds on the lower east coast and the west coast of Vancouver Island. These steps were taken to halt an apparent decline in abundance on the west coast and to prevent the possibility of a similar decline on the lower east coast. Because of the indicated presence of essentially independent runs, sub-quotas were established for individual areas on the west coast. Quotas were arbitrarily fixed at tonnages below the maximum catches of former years, but larger than the minimum catches of later years. Various adjustments have been made to the size of the quotas and to the areas covered by individual quotas as research data gave a clearer picture of the nature and size of the stocks involved.

In 1940-41 a quota of 5,000 tons was applied to the Discovery Passage region (Area 13). In 1948-49, the middle east coast sub-district was formed by combining the Discovery Passage region (Area 13) with Areas 14, 15, and 16, formerly part of the lower east coast sub-district. The quota was increased to 10,000 tons. In 1941-42, quotas were also applied to the fisheries in the northern, central and upper east coast sub-districts. In the same year, when information from the tagging program indicated that there was a considerable degree of intermixing between populations from adjacent areas on the west coast, sub-quotas were abolished there. No quota has ever been applied to fishing grounds in the east coast of the Queen Charlotte Islands.

In 1946-47 in order to determine the efficacy of quotas in regulating the catch, the quota on the west coast was removed and plans were made to study over a period of years the fluctuations in a population where no quota

TABLE 1. Quotas and quota extensions by sub-district and season, in thousands of tons.

Seasons	*Sub-districts*									
						West Coast				
	Northern	*Central*	*Upper East Coast*	*Discovery Passage and/or Middle East Coast*	*Lower East Coast*	*Total*	*Area 23*	*Area 24*	*Area 25*	*Area 26*	*Area 27*
1936-37	—	—	—	—	25*	40*	15*	5	10	10*	5
						5	5*				
1937-38	—	—	—	—	25*	40	15*	5	10	10	5*
1938-39	—	—	—	—	25*	40	15	5	10	10	5*
1939-40	—	—	—	—	25*	40	15	5	10	10	5
					10						
1940-41	—	—	—	5*	30*	40	15	5	10	10	5
1941-42	25	40	8	5*	30*	25	—	—	—	—	3
				5	20*						
1942-43	25	40	8	5	30*	25	—	—	—	—	3*
					20*						
1943-44	25	40	8	5*	30*	25	—	—	—	—	3*
					20						
1944-45	25	40	8*	5*	30*	25	—	—	—	—	—
					10*						
1945-46	25	40	8	5*	30*	25	—	—	—	—	—
					10*						
1946-47	25	40	8	5*	40*	—	—	—	—	—	—
1947-48	25*	40	8	5*	40*	—	—	—	—	—	—
	15*				(1) 5*						
1948-49	30	40*	10	10*	40*	—	—	—	—	—	—
		(2) 10*		(3) 5							
1949-50	30*	40*	10	10*	40*	—	—	—	—	—	—
	10*			4*							
1950-51	30*	40*	10	10*	40*	—	—	—	—	—	—
	20*	10*		4							
1951-52	30*	40*	10	10*	40*	—	—	—	—	—	—
	10*										
	10*										
1952-53	30	40	10	10	40						
1953-54	30*	40	10	10*	40*	—	—	—	—	—	—
				10*	10*						
					5						

(1) A quota extension of 5,000 tons granted to be taken in Area 14 only.
(2) Area 5 removed from central sub-district and included in northern sub-district.
(3) Middle east coast sub-district formed, with quota of 10,000 tons, comprising Discovery Passage Area and Area 14 (previously in lower east coast sub-district).

restrictions were applied and in a population, the lower east coast, where strict quota restrictions were maintained. The results of this experiment are discussed in more detail later.

Quota extensions have been granted in a number of sub-districts and areas when such appeared justified by the apparent abundance of herring on the fishing grounds. Since the establishment of the comparative study of the lower east coast and west coast populations in 1946-47 no quota extensions have been granted for the lower east coast population. An exception was made in 1953-54 when it was considered that there was a much larger than normal carryover of fish resulting from the failure to fish in the previous year. The quotas for the various sub-districts are shown in Table 1, quota extensions are underlined, an asterisk indicates that the quota or extension was reached or approximated.

3. Herring Research

A. Introduction

The objective of the herring investigation is to obtain scientific information on the life history and population dynamics of the Pacific herring that will provide a basis for securing the maximum annual yield from the fishery consistent with sound conservational practice.

To obtain maximum sustained yield from any fishery information is required on three important points.

(1) Does the supply of fish consist of one stock spread throughout all areas in which the fishery is prosecuted or are there a number of essentially discrete stocks present within various areas? If the former is the case, one management formula and a uniform system of regulations can be developed for the fishery as a whole; if the latter is the case, each stock may require to be treated separately.

(2) What is the relationship between natural mortality and growth rate? At what age or size is the point of equilibrium between increase in weight to the stocks through growth balanced by the loss in weight through death by natural causes? When a virgin population is first exploited the accumulation of old fish is caught off first. As fishing effort increases, the resulting average size and age of the fish in the population decreases as an increased proportion of the older fish is removed. Assuming a constant supply of recruits, total catch will increase with increasing fishing effort until the average size (or age) of the fish in the population is such that growth in weight of the population is balanced by loss through natural causes. If fishing effort is increased beyond this point a decrease in total catch will result since the population is being exploited at a time when its net weight is increasing. If this point of equilibrium occurs before the fish are recruited, then maximum yield will be obtained by taking all the recruits. This, of course, would only be feasible provided the fish also matured and spawned before recruitment, producing an adequate supply of recruits to sustain the population. However, the more usual situation

is for recruitment to occur either at or before maturity. In this case it would not be possible to take all the recruits entering the fishery for then no spawning stock would be left. The maximum sustained catch must, therefore, occur at a level of fishing intensity less than 100 per cent where sufficient escapement is permitted to ensure the production of a constant supply of recruits. Emphasis is thus thrown on the maintenance of an adequate supply of new recruits and, therefore, on the maintenance of an adequate spawning stock to keep the fishery stabilized at the optimum level of abundance.

If the point of equilibrium occurs after the fish are recruited to the fishable stock it may be possible to obtain the theoretical maximum annual yield, provided that sufficient spawning to sustain the population is provided by that segment of the fishable population which is below the size (or age) at which the point of equilibrium occurs. If this condition is not fulfilled, then maximum sustained catch will again occur at some lower level of fishing intensity that would permit adequate escapement.

(3) The relationship between the number of spawners and the number of new recruits must, therefore, be established. Theoretically in a fish population the relationship between the amount of spawn deposited (or the number of spawners) and the resulting recruitment is such that there is a direct relationship up to a certain point beyond which a further increase in spawn deposition produces no further increase in recruitment. This arises because of decreased survival resulting from increased population pressure (overcrowding and consequent greater loss because of increased competition for food, increased incidence of disease, etc.). The point at which the direct relationship between the amount of spawn deposited and the resulting number of recruits ceases is theoretically the optimum size of spawning population for producing maximum yield in numbers.

Data on a number of other points are required for the interpretation of information on the three points discussed above. The life history of the species, the fecudity, the age of the fish at maturity, the age or ages at which recruitment to the fishable population occurs, the sex ratio, the age composition of the fishable stock, the exploitation rates and estimates of the amount of spawning escapement in the various stocks must be known.

It is realized that natural populations are never static. From year to year, varying environmental conditions will produce variations in the size of the year-class resulting from a constant amount of spawn deposition. It is, therefore, obviously not feasible to ensure a constant number of recruits to a fishery. What can be done is through a knowledge of the factors affecting survival to recruitment, to estimate the size of the resulting year-class at recruitment and then to regulate the fishery so as to allow sufficient escapement to produce again the desired amount of spawn deposition. Therefore, a knowledge of factors influencing survival of the spawn, of the larvae, and of the juveniles, as well as of the adults is of importance in maintaining the annual catch at the highest sustained level.

B. Present Knowledge

The object of the research carried out by the herring investigation is to obtain as complete answers as possible to the foregoing questions. The more important results obtained to date are as follows:

(1) **Major Herring Stocks.** The herring stocks in British Columbia waters consist of seven major essentially discrete populations in the following regions: the east coast of the Queen Charlotte Islands, the northern, the central, the upper east coast of Vancouver Island, the middle east coast of Vancouver Island, the lower east coast of Vancouver Island and the west coast of Vancouver Island sub- districts. Small local populations occur in nearly all sub-districts but more particularly in the middle east coast, upper east coast and central sub-districts. The existence of distinct populations was demonstrated by racial studies involving, in particular, mean vertebral number, *(29, 41, 89,* and *115),* and by a tagging and tag recovery program *(15, 18, 20, 22, 24, 25, 27, 28, 29, 30, 62, 68, 69, 70, 72, 103, 104, 109, 112, 120, 121, 124, 126).*

The results of studies of mean vertebral number also indicated that the herring populations inhabiting each of the areas within the west coast sub-district formed essentially discrete populations with limited intermixing. The results of the tagging program partially confirmed this but indicated that mixing was more than "limited," that, while generally speaking, about 55 per cent of the stock returned to the area of tagging, 45 per cent wandered to other areas, with a greater proportion going to contiguous areas than to more distant areas *(115).* It was on the basis of these findings that the catch quotas and later the modifications to them were established.

(2) **Age Composition.** Information from the annual sampling program initiated in 1929 has shown that the fishery depends almost entirely on mature herring, taken during their inshore spawning migration. These runs consist of fish of Ages I to XI with the great proportion (80 to 90 per cent) of Ages III to VI. In the southern waters of the province recruitment occurs mainly at Age III and to a lesser extent at Age IV. In northern waters a greater proportion of the recruitment occurs at Age IV than in the southern waters. In both the north and south some recruitment occurs at Ages I and II, but is of minor importance. In the catches, Age III forms the dominant age-group in the south and Ages III and IV in the north.

The sampling program has also shown that considerable variations exist in year-class strength. The presence of dominant year-classes has been indicated. These strong year-classes make their presence felt in the fishery for only a relatively short period, usually two to four years. The fluctuations in abundance in the various sub-districts have been attributed mainly to variations in the relative strengths of the year-classes contributing to the stocks.

(3) **Natural Mortality.** Natural mortality rate (percentage decrease from one age group to the next) may be estimated from the average age composition of virgin or near-virgin populations. Samples from two such populations are available, from the Barkley Sound population in 1915-16 and 1916-17, and

from the Queen Charlotte Islands population during the first four years of fishing (1938-39 to 1941-42). The Barkley Sound samples indicated a natural mortality rate of 60 per cent between Ages VI and XI. The Queen Charlotte Islands samples indicated an average mortality rate of 50 to 60 per cent between the same ages, with definite indications that the mortality rate increases with age *(50)*. Data from Barkley Sound on the average weight of herring over a 16-year period indicated that growth is much more rapid in early than in later years of life. The weight increment is large between Age I and II (225 per cent) but decreases rapidly and consistently with increasing age to a very small increment (4.5 per cent) between Age VIII and IX. The increment between Age II and III is 67 per cent, between Age III and IV 25 per cent and between Age IV and V 15 per cent. The rate of increase, therefore, of the fishable population from growth in weight is much less than the rate of decrease from natural mortality. Therefore, maximum yield will be obtained with an intense fishery, the intensity being as great as is consistent with the maintenance of the supply of young *(114)*.

(4) **Efficacy of Catch Quotas.** A fishery as intense as is consistent with the maintenance of an adequate supply of young is required for the most effective and efficient exploitation of the herring stocks. In view of this fact two important and to a degree interrelated questions arise. One concerns the efficacy of catch quotas in regulating the fishery and the other the relationship between the amount of spawn deposition (or the size of the spawning stock) and the size of the resulting year-class. To derive information on these two questions, quota restrictions were removed in 1946-47 on fishing in the west coast sub-district, while at the same time the quota on the lower east coast was increased to 40,000 tons with the understanding that it be rigidly maintained at this level. The intention was that this population should act as a control against which fluctuations in the west coast populations resulting from unrestricted fishing could be assessed. It was also considered that by permitting increased fishing effort on the west coast, the stocks there might be reduced to a level where spawn deposition and resulting year-class strength would become directly proportional. This should allow the determination of the point beyond which an increase in spawn deposition failed to produce an increase in the resulting year-class. It is at this point that the maximum number of recruits is provided by the minimum size of spawning stock, or in other words, the point at which maximum catch consistent with the provision of an adequate supply of young occurs.

Prior to the inception of this program all the available data indicated that there was no apparent relationship between spawn deposition and year-class strength; good year-classes had resulted from poor spawnings, and poor year-classes from medium or good spawnings.

During the first five years (1946-47 to 1950-51) high population abundance characterized the lower east coast and the west coast populations. In the sixth year (1951-52) population abundance was reduced sharply on the west coast, but remained hgh on the lower east coast *(69)*. The lack of a fishery in 1952-53

prevented the determination of the effects of unrestricted fishing on the west coast stocks during a period of low population abundance.

The results of this study to date indicate that during periods of high population abundance, quota restrictions on fishing on the west coast population appear unnecessary to maintain an adequate spawning stock. Spawn deposition shows no relationship to future recruitment. It appears that natural restriction on catch imposed particularly by late inshore migration in certain areas and also by the size and geographical configuration of the region are effective in limiting exploitation during periods of high population abundance. However, whether they are sufficiently effective during periods of low population abundance remains to be determined *(72)*.

On the lower east coast for the past seven years with the exception of 1952-53, the quota has accounted for between one-half and three-quarters of the total lower east coast population each year, while unrestricted fishing on the west coast has attained a comparable degree of exploitation in one year only (1947) *(72)*. The simple pattern of inshore migration of the lower east coast stocks through a continuous series of fishing localities renders this stock particularly susceptible to excessive exploitation. At the present rate of exploitation there is some evidence pointing to a tendency for year-class strength to be directly related to the amount of spawn deposited *(72)*. Furthermore, there is good evidence that further catches could have been made on the lower east coast after the quota was taken and, therefore, that a higher rate of exploitation could be attained if quota restrictions were removed. The possibility, therefore, may exist that removal of the lower east coast quota might result in such high exploitation that the spawning stocks would be reduced to a level where future population abundance would be endangered.

Detailed information on the comparative study of the lower east coast and west coast populations is contained in the Annual Reports of the B.C. Department of Fisheries from 1946 onwards *(62, 68, 69, 70, 72, 124, 126)*.

While detailed studies have not been made to date of the effectiveness of quotas in other sub-districts there are indications that the exploitation rates attainable under these quotas are of the same order as those in the lower east coast and west coast of Vancouver Island sub-districts.

(5) **Spawn Surveys.** For many years spawning ground surveys have been carried out by the Inspectors of the Federal Department of Fisheries. In earlier years (1930-36) the inspectors made qualitative observations of the individual spawnings that came to their attention. From 1937 onwards efforts were made to obtain more detailed, complete and uniform information. Herring spawn surveys became a regular part of the inspectors' duties and they were required to patrol their areas during the entire spawning period and to submit information on the date, length, average width, depth and intensity of egg deposition on each individual spawning. In 1946-47 when the comparative study of the lower east coast and west coast populations was initiated, annual, independent spawn surveys on the west coast were undertaken by members of the herring

investigation. The purpose was to provide more detailed information on spawnings on the west coast and to study factors affecting spawn survival.

Besides indicating that under existing levels of fishing intensity there was no apparent direct relationship between the amount of spawn deposited and the resulting year-class strength, certain information has been obtained on the factors affecting the survival of spawn. Bird predation on individual spawnings has been found to be variable but generally severe, resulting in mortalities of 30 to 90 per cent. However, the net effect is presumed to be relatively constant from year to year. The location of the spawning area itself, the location of the spawn on the beach and the type of substrate have also been found to affect survival. Survival is highest in locations partially protected from wave action and least in both exposed and well protected localities; it is higher when the eggs are deposited on eelgrass and lower when the eggs are deposited on rockweed, sedgegrass and detritus; it is highest near zero tide level.

In general, it is believed that variation in the amount of spawn is not as important in producing variations in year-class survival as variations in the survival of larvae and juveniles.

(6) **Larval Studies.** From 1947 to 1951 field studies on larval herring off the west coast of Vancouver Island were carried out. The purpose of these studies was to determine the distribution of the larvae and to assess the factors affecting their survival. The salient features of larval distribution were determined and the tentative conclusion was reached that the survival was related to the degree of dispersion from the spawning locality, the greater the degree of dispersion the less the survival.

There is evidence that the period of early larval life (i. e. the month of April) may be a critical period in herring survival. A statistically significant inverse relation has been obtained between the amount of northwest winds on the west coast of Vancouver Island in the month of April and the recruitment of the year-class subjected to those wind conditions. It appears that when the April winds are dominantly northwest a strong surface current flowing offshore is produced, and heavy larval mortality results *(62)*. There are also indications that annual variation in amount of river runoff may lessen or increase the flow of this current and thereby modify the effect of winds on larval survival and eventual recruitment.

(7) **Juvenile Studies.** Preliminary studies on the distribution of young juvenile herring (after metamorphosis) were begun in 1950. It became apparent that juvenile herring were not as subject as the larvae to decimation by adverse environmental conditions because they were able to a degree actively to seek out and maintain themselves within a desirable environment. Intensive studies on juvenile distribution and abundance have been carried out in the Barkley Sound area of the west coast of Vancouver Island since 1951. The main purpose was to determine whether it was possible to predict year-class strength at recruitment from the abundance of juveniles two and a half years earlier and

also to obtain information on the environment factors governing their distribution and abundance.

Results to date have indicated that within Barkley Sound there is a number of sub-populations of juveniles, between which mixing is usually less than 30 per cent. These populations tend to concentrate in inlets and in the lee of large islands. The locations of the rearing grounds appear to bear no evident relationship to the spawning grounds and may often be at some distance (10 to 20 miles) from them. Juveniles remain within the Sound during the summer and migrate seaward in early fall. It is still too early to be able to determine whether there is any relationship between juvenile abundance and year-class size at recruitment two and a half years later.

C. Future Plans

(1) Continuing Programs

(a) The coastwise coverage of the present sampling program and fisheries officers spawn surveys will be continued. These two programs, together with information on catch, provide the basic data required for the prediction and assessment of the fluctuations in population abundance in the various sub-districts.

(b) The main purpose of the tagging program has been to define the major herring stocks in British Columbia waters and to assess the extent of intermixture between them. It is considered that for the purpose of regulation and management these objectives have largely been achieved. The extensive coastwise tagging program will, therefore, be discontinued. In the future intensive adult and juvenile tagging may still be necessary in certain areas to answer certain specific questions. One of the most important immediate problems involved here is the relationship between the young produced in an area and the mature adults spawning there.

(2) **Planned Programs.** These are programs which it is hoped to initiate in the relatively near future.

(a) To obtain all the information necessary on the effects of unrestricted fishing from the present comparative study of the lower east coast and west coast populations, this experiment would have to be continued indefinitely until natural fluctuations in year-class strength resulted in a period of low population abundance. A more definite approach is required. It is, therefore, planned to discontinue the present comparative study and to substitute a better designed controlled experiment in another area.

(b) To assess year-class strength prior to recruitment, determinations of juvenile population size will be employed in certain areas.

(c) Improvements in existing methods and the development of new methods of estimating the size of the spawning stock are planned. At present a factor derived from the extent and intensity of spawn deposition is used as an index to the size of the spawning stock. It is planned to attempt to estimate the

spawning stock directly by echo-sounding surveys of the grounds after the fishing season.

(d) It may be possible from the extent and intensity of spawning (number of eggs per sq. ft.) and from knowledge of herring fecundity to form an estimate of the size of the spawning escapement. While reliable information on extent and intensity of spawn deposition are available from the spawn surveys, there is little detailed information on fecundity. It is planned to undertake studies to determine the variation in the various stocks in the numbers of eggs with the size and age of the female.

(e) It is planned to undertake experiments to improve tag recovery methods. At present tags are recovered either on magnets placed in the meal lines in the reduction plants or by induction type detectors placed in the unloading machinery. The information provided by detector recoveries is by far the more reliable. Unfortunately the necessarily small size of the metal tag results in a low signal-to-noise ratio and somewhat unstable detector operation. It is, therefore, planned to undertake experiments to improve detector efficiency and stability.

(3) **Projected Programs.** Consideration is being given to programs to study:

(a) The factors influencing the migration of adult herring, particularly the inshore spawning migration. An understanding of these factors might enable prediction to be made of the time and place of such migrations, thereby, permitting more efficient disposition and control of the fishing fleets.

(b) The period in the life history between offshore migration as juveniles in the fall of their first year and recruitment to the adult stocks one or two years later.

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The credit for the accomplishments in herring research on the Pacific coast of Canada belong both to those who have had the responsibility for planning and supervising the various projects and to those who were responsible for carrying them out. No individual acknowledgment can be made here of the important contributions of the latter group beyond the references to their work in the accompanying bibliography. In the former group, reference must be made of the outstanding part played by Dr. A. L. Tester, now of the University of Hawaii, who was largely responsible for the basic planning of the research and who set the tone of much of the subsequent work, and by Mr. J. C. Stevenson, now assistant director of the Pacific Biological Station, who succeeded Dr. Tester in the supervision of herring research. Dr. J. L. Hart, director of the Atlantic Biological Station, made an important contribution to herring research both directly in the earlier years of the investigation and also later during his tenure as director of the Pacific Biological Station. The interest and encouragement shown by Dr. A. W. H. Needler, director of the Pacific Biological Station, in the planning of future herring research projects is gratefully acknowledged.

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PROBLEMS OF PACIFIC SALMON MANAGEMENT

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THE RESOURCES

Five species of Pacific salmon (genus *Oncorhynchus*) occur on the western coast of North America, namely: the spring or chinook salmon (*O. tshawytscha*); the coho or silver (*O. kisutch*); the sockeye, red or blueback (*O. nerka*); the pink or humpback (*O. gorbuscha*); and the chum (*O. keta*). All these species are commercially valuable in British Columbia, and the first two also provide an important sport fishery. The average annual commercial salmon catch for the province is about 180 million pounds, the marketed value in 1953 was approximately $48,000,000.

This catch has remained fairly constant for some 40 years—a long period by the standards of West Coast history. It might be inferred, therefore, that the fishery is in a satisfactorily stable condition and that the sustaining of current practices and regulations would permit production to continue on the same scale for an indefinite period. Actually, preservation of the salmon fisheries in the past has depended on periodic adjustments rather than on the maintenance of the *status quo* and there is every indication that future conservation will present increasing difficulties and will necessitate radical changes in the management of the resource.

In comparison with the early years of the fishery, volume of production is now maintained by increased utilization of pink salmon and chum salmon which were formerly not exploited as intensively as the other species, especially sockeye. Production of the latter species, in spite of recent and encouraging increases in the Fraser River watershed and well-sustained abundance in the Rivers Inlet area, remains well below the level obtaining in the early years of the century. In recent years, exploitation of all species has been heavy

and fishing effort so thoroughly distributed on all parts of the British Columbia coast that there is little chance of increasing the annual catch significantly by the discovery of under-exploited stocks. Consideration is now being given to the possibilities of greater catches by extending fishing into more off-shore waters, out into High Seas areas. Since salmon must, for spawning, come into inshore waters and into rivers and streams, such off-shore operations can only result in capturing, earlier in the season, salmon that would be taken later in coastal waters (probably more economically), or in tapping stocks produced in and subsequently bound for other areas, Alaska or the Pacific States of the United States, where they would eventually normally be caught. Any such off-shore or High Seas salmon fishery, exploiting probably mixed stocks whose rivers of origin are unknown, would greatly complicate the conservation programs for the various river systems.

PRESSURES AND DANGERS

To offset heavy fishing pressures an increased rate of natural reproduction becomes necessary, in other words, a greater percentage production of young salmon to swell the stocks in the sea. This applies to the fresh-water part of the life cycle. Present developments are, however, tending to restrict or impair the effectiveness of those fresh-water habitats which are essential for reproduction success. The major detrimental factors are deforestation, hydro-electric dams and other impoundments, diversion of water for irrigation or domestic uses, and pollution. The adverse pressures brought to bear are not exerted equally on all watersheds or on all species of salmon but their effect is indeed very real.

Deforestation. The most widespread of the above-mentioned pressures is deforestation. By removal of the forest cover, the normal flow of streams is altered. Rapid changes in flow patterns occur. Flash floods, with damaging stream-bed scouring effect, develop, to be followed by low flow during dry weather. Severe erosion of stream banks and adjacent terrain occurs to cover up the salmon redds or impede the proper percolation of water through the stream-bed gravel areas. Stream water temperatures rise, especially during summer months. In most cases of suspected stream deterioration actual quantitative studies of the effects of removing forest cover are lacking and it should be recognized that a great many salmon streams show much fluctuation in run-off even under undisturbed conditions. Nevertheless, a correlation has been shown to exist in Oregon between the decline of coho runs and the progress of deforestation (McKernan, Johnson and Hodges, 1950). On the east

coast of Vancouver Island pink salmon populations declined following extensive logging operations and in some instances improvement of the runs has coincided with development of second-growth forest cover. In the case of the Cowichan River, Vancouver Island, stream flow records show that the average summer discharge was higher in the period 1913-1919 than in the years 1940-1946. Much deforestation took place between these periods. A positive correlation was shown between the summer discharge and the abundance of cohos two years later (Neave, 1949). Furthermore, the virtual disappearance of a population of early-running chinook salmon which formerly entered this river in the spring and remained in the water-shed until early autumn spawning time is ascribed (*loc. cit.*) to increased summer temperatures caused in part by deforestation.

Man-made obstructions. The most serious of these are dams constructed to provide hydro-electric power or to store water for other purposes. These structures form barriers to salmon migration and in some cases divert water from existing river beds. The necessity of providing ladders or other devices to enable migrating fish to surmount dams is fully recognized, and large migrations take place annually over or around some of these of relatively moderate height, for example, the Bonneville Dam on the Columbia which is around 60 feet high. No really successful method has yet been demonstrated, however, for by-passing the much higher dams, which are now under construction or are projected, where large runs of salmon are involved.

The dangers encountered by young salmon migrating seaward are sometimes even greater. Many fish are killed by falling over high spillways or as they endeavor to make a hazardous passage through turbine intakes. Adequate screening of these danger spots has not hitherto proved feasible. The cumulative effect of a series of dams in a river system, each taking a toll of the passing fish, may seriously deplete a population at a stage long before the survivors present themselves to the attention of the fishery. A 10 per cent loss at each of several dam sites can quickly represent a severe drain on any stock.

The Columbia River is one river where the up-and-down-stream movement of salmon has been appreciably affected by power dams. The degree of loss is still debatable, perhaps, but it seems to be significant that of spring (chinook) salmon tagged off the west coast of Vancouver Island in recent years the proportion recovered in the Columbia amounted only to 15 per cent as compared wiht 65 per cent in similar taggings conducted 25 years ago (Milne, 1953).

In British Columbia, dams have not yet caused widespread interference with salmon runs. Future developments, however, pose drastic threats.

Species' differences. While all species are faced with difficulties and dangers in fresh water, the problems differ to some extent in kind and magnitude. Sockeyes and chinooks, which frequently undertake very long migrations in the larger river systems, are very vulnerable to large-scale development schemes. Sockeyes, in addition, require lakes with sufficient food supplies to permit development for a year or longer. Cohoes are widely dispersed and do not require lakes (though some do frequent lake areas for their year's residence (Foerster and Ricker, 1953) but since the young fish live for a full year in streams they are exposed to the whole range of seasonal fluctuations in discharge, temperature and food supply. Pinks and chums are basically dependent on fresh water only for incubation of the eggs and alevins. By their early passage to sea the young fish avoid the limitations imposed by restricted food supplies and unfavourable summer conditions. Moreover they inhabit principally small streams or the lower reaches of larger rivers, thus escaping some of the man-made perils of a long migration. These spawning grounds are, however, frequently very sensitive to changes in water flow; even during the short journey to salt water the fry are subjected to heavy mortality by predators.

PRESENT CONSERVATION PRACTICE

The essential basis of past and present conservation measures is to ensure that a substantial proportion of the maturing fish is allowed to get through the coastal and river estuary fishing areas and proceed upstream. This "spawning escapement" is provided by prohibiting fishing at certain times and by restricting the kinds and sizes of gear, as well as the manner of their employment. With certain exceptions, fishing in fresh water or near the mouths of streams, where fish tend to congregate, is prohibited.

The problems involved in endeavouring to provide an adequate spawning escapement are two-fold. In the first place, the difficulty of assessing an incoming population and of effecting a given division between catch and escapement is very real. Secondly, there is a lack of fundamental information as to the size of spawning escapements which can be expected to produce the most beneficial results. Hitherto there has been a tendency to think of escapement in terms of a percentage of the total mature population. In the case of the Fraser River sockeye a spawning population representing around 20 per

cent of the run has been considered sufficient to maintain existing levels of abundance. For other areas, notable Alaska under the White Act, and for other species there has been a tendency to regard 50 per cent as a standard to be aimed at. In theory it would seem that escapement should approximate to a fixed number rather than to a percentage of the run, this fixed number being related to the quality and capacity of the particular watershed for spawning and for rearing the young. In most instances, present knowledge is insufficient to set numerical objectives; yet, in spite of imperfections due to inadequate information, the efforts which have been exerted to provide sizable escapements have undoubtedly been the main factor in keeping salmon production at a relatively high level up to the present time.

Other conservation measures in recent years have been directed principally toward maintaining and increasing the accessibility of spawning grounds to the adult fish. Thus, as many as possible of the salmon that have escaped the fishery may safely get to suitable spawning areas. Providing fishways to by-pass natural or artificial obstructions is a standard practice (Talbot, 1950; Anon., 1953a, 1954a, b, c). Removal of log jams (a common feature of many salmon streams) is undertaken when necessary, but the advantages of protective cover and the effectiveness of sunken logs in checking erosion make general "clearing out" of streams undesirable. A spectacular recent stream clearance operation was the removal, at a cost of some $600,000, of a natural rockfall which in 1951 obstructed the very important salmon runs of the Babine River in a remote part of the Skeena watershed (Anon., 1953b; Godfrey, Hourston, Stokes and Withler, 1954).

Under natural conditions, the downstream migration of young salmon receives, and perhaps requires, less attention than the spawning run. At times, however, numbers of migrants or feeding young become trapped in pools by dropping stream water levels. In some years the freeing of such fish, by netting out or constructing exit ditches, results in potentially important savings, notably in certain streams on the south-east coast of Vancouver Island. In at least one year the number of chum and coho fry released in this way was estimated at over a million in the Cowichan River alone (Neave, 1949).

PRESENT RESEARCH

Heretofore salmon fishing has been essentially the gathering of an uncultivated crop of fish whose abundance has depended on great

areas of land and water being left in their primitive condition. Whether we like it or not, this state is being changed and will be changed more. A management policy which merely tries to perpetuate primitive conditions will not succeed, except perhaps in certain especially designated and limited areas.

Broadly speaking, therefore, present management aims must be four-fold: (1) to regulate the fishery in such a manner that the spawning escapements are capable of maintaining a high level of abundance, (2) to develop ways of minimizing the deleterious effects of human activities on freshwater habitats, (3) to increase the productivity of spawning and nursery waters which remain accessible to salmon and (4) to open up and develop new ones for reproduction. In broadly based management or research programs no strict separation of these four categories can or should be expected.

Regulation. Regulation of the fishery to provide satisfactory spawning escapements is an internal matter in that it can be effected by the industry itself and the appropriate governmental agencies. An excellent system of recording catch by species, time, and area, has recently been put into operation. Sampling of the commercial landings to determine the constituent age-classes of salmon makes it possible to designate the productiveness of the previous years' spawnings. It has to be recognized that as fishing operations extend farther offshore and out into the high seas it is going to be much more difficult to relate the catches to individual river systems or coastal areas. Therefore the establishment of catch to escapement ratios and regulation of catch to assure adequate escapement will become much more complicated and difficult. The difficult problem of estimating spawning escapements is tackled on a comprehensive scale, although results must be regarded as largely qualitative. In many cases the extent of country involved and the remoteness of many of the spawning areas makes patrol and examination costly and difficult.

Production in fresh water. The best-laid schemes for regulation of the fishery will come to naught if the fish which the industry refrains from catching are unable to reproduce. Reference has already been made to the problems presented by natural and artificial obstructions and the efforts to overcome them. The deleterious effects of log jams also are being alleviated. In addition, however, every effort must be made to assure that natural production be fully effective, *i.e.*, that egg deposition be as complete and as successful as possible and that the survival of the young fish up to the time of passage into the sea be as high as possible.

For many years, in British Columbia as elsewhere, it was thought

that the answer to producing more salmon lay in hatcheries. Widespread use was made of them, particularly for the propagation of sockeyes. A 12 year investigation at Cultus Lake, B. C., showed that this kind of artificial propagation was not improving significantly on the results of natural reproduction (Foerster, 1938). The essential features of the view resulting from this investigation are that where conditions for natural propagation remain favorable (1) little or no advantage is gained by the substitution of hatchery procedures terminating at or before the fry stage of the life-cycle, (2) the protection and care of the young fish to a later and less vulnerable stage, in the numbers required to support the commercial fishery, would be unreasonably costly.

This verdict would not necessarily apply to situations in which natural propagation is restricted or impaired, and it might also be altered by changes in the value placed on the resource. Under present conditions, however, hatcheries do not provide a blanket beneath which salmon management can take cover. As a routine practice the operation of salmon hatcheries has been discontinued in British Columbia since 1937.

One purpose of two research projects of the Fisheries Research Board of Canada has been to ascertain, for sockeye and for pink and chum salmon, the normal range of survival during the various stages of the life-cycle in fresh water and the average overall percentage of production of seaward migrants, whether fry (in the case of pinks and chums) or one or two-year smolts (in the case of sockeye), from a known spawning or egg deposition. At the same time observations are made as to the factors which contribute to the non-survival or mortality. The production data then act as a basis for evaluating any improvement measures that might be taken or for assessing the trend of freshwater production as environmental conditions change. The observations on possible limiting factors for survival serve to reveal which factors are most important and whether they can be remedied or not.

For pink and chum salmon, the over-all fry production, as summarized by Neave (1953) and Hunter (unpublished), has been found to be:

Species	Locality	Number of years	Geometric mean Survival(%)	Range(%)
Pink Salmon	McClinton Creek	6	13.15	6.9-23.8
Pink salmon	Morrison Creek	2	5.61	4.7- 6.7
Pink salmon	Hooknose Creek	7	8.13	0.9-16.4
Pink salmon	Sashin Creek, Alaska	6	1.16	0.2- 4.4
Chum salmon	Nile Creek	5	0.30	0.08-6.03
Chum salmon	Hooknose Creek	7	8.69	1.0-19.4

Breakdowns of total freshwater mortality encounter two main difficulties (Neave, 1953). The first lies in the absence of quantitative data indicating the variation which undoubtedly exists in different streams and different years. The second is that many of the factors are so interrelated that assignment of losses becomes an arbitrary matter. For example, the losses among pre-spawning fish or among the young may be assigned largely to a biological factor, predation. The extent of predation may, however, depend greatly on a non-biological factor, the prevailing water level of the stream. On the other hand, to report such factors as stream-bed scouring or silting as the chief causes of mortality among eggs and alevins may underemphasize the part played by a biological factor, the size of the spawning run, which may determine the proportion of fish forced to select less desirable spawning sites. On the whole, however, it has been established that (a) variations in water levels and water flow in streams at spawning time and during fry emergence and seaward migration and (b) predation on fry are important factors. Some control measures may be practicable and effective.

It has been shown experimentally (Wickett, 1952) that more young pink and chum salmon can be produced from a given area by concentrating eggs in channels where water flow is controlled, where stream-bed gravel conditions are uniformly favorable, and where predators can to some extent be excluded. In theory, the fresh-water requirements for a population of either species equivalent to the whole existing British Columbia stocks could be met by incubation areas totalling only one square mile, 640 acres. The difficulties of concentrating eggs and ensuring their favorable distribution in the selected places—the problems of providing the right conditions of substratum and water flow—need not blind us to the fact that much may be done beyond wringing our hands at the encroachments of industry.

A small-scale example of the kind of development that can be expected to take place is provided by Wahleach Creek, a salmon-bearing tributary of the Fraser River. As a result of hydro-electric development the flow of this stream has been reduced to a point at which natural propagation might be expected to suffer. In conformity with requests by the Department of Fisheries the B. C. Electric Company constructed an artificial channel, with a gravel bottom and a head-gate for control of water supply (Anon., 1954d). Under the more constant water conditions thus created, the stream may be capable of maintaining an even greater output of young pink and chum salmon than formerly.

As for loss of pink and chum salmon fry through predation during their short-term migration seaward it has been found that large populations suffer relatively less than small ones (Neave, 1953). In the limited time available, the local predators cannot use more than a certain maximum number of fry and large runs therefore take a lower percentage loss than small runs. This is an additional reason for trying to obtain the maximum fry hatch which a stream can produce, thus "swamping" the predators and reducing their influence on salmon fry populations.

For sockeye salmon, the one- or two-year residence in a lake provides that (1) the young fish go to sea at a much larger size and therefore may suffer appreciably less ocean mortality; (2) the losses from fry to smolt stages may be equally as great in fresh water as they would be for pinks and chums in the sea but nevertheless they presumably may be more readily assessed and perhaps remedied and controlled; and (3) the size of population will be limited by the productive capacity of the lake which each race inhabits.

Studies of natural production of young have been made in four areas which differ quite markedly in climate, size and geographic location (Cultus Lake, a tributary of the lower Fraser River (Ricker, 1937); Port John, in the Central coastal area (Robertson, 1954); Lakelse Lake, a tributary of the lower Skeena River (Brett and Pritchard, 1946); and Babine Lake, a tributary of the upper Skeena (Withler, McConnell and McMahon, 1949)). From test streams tributary to the lakes, percentage fry production from known egg depositions has been determined; from counts of estimations of seaward-migrating smolts, the production of smolts from known egg depositions has been computed. These are as follows:

Locality	Fry survival (per cent	Smolt production (percent)
Lakelse	13.7, 9.3, 13.6, 12.2, 10.1[1]	1.1, 0.4, 1.5, (8.5)[2]
Port John	25.2, 1.8, 5.1, 8.9, 5.0, 13.4[3]	0.5, 3.0, 5.0, 3.0[3]
Babine	12.0, 19.0[4]	0.5, 0.8, 1.5, 0.7[5]
Cultus		1.13, 1.05, 3.16[6]
Geometric mean	9.7	1.42

(1) MacDonald, J. G., Unpublished. (2) Brett and McConnell, 1950; Foerster, 1952. (3) Hunter, 1949, and unpublished. (4) Withler, F. C., unpublished. (5) Withler, 1953, and unpublished. (6) Foerster, 1938.

Sockeye fry survival ranged from 1.8 per cent to 25.2 per cent, the geometric mean being 9.7 per cent. This is similar to the percentage production of pink salmon fry obtained in British Columbia

test streams and is slightly greater than that for chum salmon at Hooknose Creek. For sockeye smolts, however, production was found to be 1.42 per cent of eggs deposited. It becomes apparent, therefore, that for sockeye, the losses occurring in spawning, incubation, fry emergence and passage from hatching area to lake amount to approximately 90 per cent of eggs available for deposition (*i.e.*, contained in females passing the counting weirs) while the losses in the nursery lakes amount to about 85 per cent of the fry entering them.

A rough breakdown of the mortalities occurring during the various phases of the life-cycle of sockeye, from the time of up-stream spawning escapement to the seaward migration of smolts, and computed on the basis of 4,000 eggs per female, might be made as:

Losses during upstream ascent—10 per cent or 400 eggs. 3600 eggs remaining.
Losses during spawning and incubation in redds—50 per cent or 1800 eggs. 1800 alevins produced.
Losses during fry hatch and migration to lake—75 per cent or 1350 alevins. 450 fry produced.
Losses in lake—85 per cent or 383. 67 smolts produced.

Such breakdown is admittedly very crude and will vary appreciably from locality to locality, from season to season, and according to size and density of the spawning population. It serves to indicate, however, where the heavy losses occur and suggests where effort might most effectively be applied to increase production. It tends to show, also, where and how changes in environment and water conditions caused by man-made developments may affect sockeye production. If, as has been indicated by one series of findings (Foerster, 1937), the return from the ocean be 10 per cent of the smolts entering it, the 67 smolts produced from the spawning of one pair of sockeye (4000 eggs) will return 6.7 adults, a production ratio of 6.7:2, thus producing a surplus or dividend of over 300 per cent. Out of each seven sockeye returning from the ocean, therefore, approximately five can be removed by the fishery and two allowed to proceed to the spawning grounds.

Reference has already been made to the probable beneficial effect of stream water control in increasing production of pink and chum fry. The same will apply to sockeye, though perhaps not as generally, since in many areas the sockeye spawn in gravel reaches below lakes where water flow conditions are relatively stable. Predation on fry in the streams and on fingerlings in the lakes is a serious limiting factor. Reduction of the number of predators in one area, Cultus

Lake, was attempted (Foerster and Ricker, 1941) and resulted in a notable increase in sockeye smolt production. The feasibility of applying this kind of protection to important stocks of salmon merits thorough exploration. It involves a long-term study of interspecific relationships to determine how readily and at what cost populations of predator species can be kept under control.

Evidence available suggests that the production of sockeye is limited by the capacity of lakes to support large populations of smolts (Foerster, 1944). Smolt size, inversely related to the density of lake population, appears to influence directly the survival in the ocean (Foerster, 1954). Therefore, consideration is being given to the feasibility of increasing the productive capacity of lakes by fertilizing with essential mineral and organic fertilizers to stimulate greater crops of food. This represents another means of increasing sockeye production and its value should be determined.

The possibilities of favorable action are more encouraging because some lakes have produced and are producing sockeye crops far in excess of the average. Lakes of the Rivers Inlet and Smith Inlet watersheds of British Columbia today produce average sockeye catches of around 40,000 fish per square mile of lake area which is 15 times the average production of the Skeena or Fraser systems, on a lake-area basis. Even greater production occurred, apparently, in the Karluk Lake, Alaska, area in the early years of the century, the average catch amounting to about 150,000 sockeye per square mile of lake area.

CONCLUSION

The chief objective of salmon management is obviously the production of as great a harvestable surplus as possible. This means, firstly, that full use must be made of the capacity of all available salmon-producing areas and that only sufficient fish be saved from the commercial fishery to re-seed the spawning beds fully and to fill the lakes (sockeye) and streams (coho) to full productive capacity. Data on these points are being obtained, as already indicated. It means, secondly, that wherever possible new areas should be opened up to salmon production. This is being done by removing obstructions or by building fishways around them. It means, thirdly, that steps should be taken to increase production in presently-utilized areas, by improving stream conditions, by reducing predators, by raising the potential productive capacity through fertilization of lakes or by providing artificial spawning areas. These possibilities are all being investigated. It means, fourthly, that the advance of civilization and the inroads of industry through removal of forest

cover around streams, construction of hydro-electric dams, increase in pollutants poured into rivers and coastal areas, diversion of water for domestic or irrigation purposes and the like, must be carefully watched, the damaging effects remedied where possible and the general overall effect on production assessed so that in the balance sheet of salmon production the unavoidable losses may be computed and counterbalanced by greater productive efficiency elsewhere.

It has to be realized that in the management of any biological resource there are to be expected wide fluctuations in production, caused by changes in environment, of climate and by the influence of changes in populations of other fish inhabitating the same waters. There will be periods of high natural production, periods of low. All that man can do is work with nature and give it a fair chance.

Where, as in the case of the Pacific salmon, heavy and what-might-be-termed mass mortalities occur (*i.e.,* freshwater losses of 90 per cent or more and subsequent ocean mortalities of 90 per cent or greater) unusually favorable environmental conditions for survival may very appreciably, even explosively, increase the numbers of adults returning from the ocean in the cycle years. For example, a 50 per cent reduction of the sockeye losses at each stage between spawning and fry migration to the lake would increase smolt production by almost 400 per cent. If, furthermore, the lake losses were reduced by one-half, *i.e.,* to 42.5 per cent, the smolt output would rise handsomely and allow a very appreciable increase in both catch and escapement. By the same token, decidedly adverse environmental conditions for production may quickly reduce production of young and seriously limit the stocks returning from the ocean.

There are indications in the history of some of the salmon fisheries that extraordinary situations of this kind have occurred but the evidence is not too clear. It is apparent that greater attention must be paid to conditions existing in freshwater for survival and production of young, to improve the conditions where possible and at least to ensure that they are not adversely affected by man-made changes in the freshwater environment. Relatively small changes in percent survival of young can have a marked affect on the size of returning adult salmon runs.

Hopes for continued abundance of salmon to support a flourishing industry and to maintain an important food resource seem to hinge on our ability to develop a sort of semi-cultivation of salmon whereby inroads into primitive habitats are balanced by well-planned improvements in other places. Also there must be a realization on the part of industrial developments which infringe upon the salmon re-

source that the requirements of the salmon must be protected and safeguarded or else checked off as a charge against the value of the adversely-affecting industry. By careful planning and proper manipulation there is no reason why salmon production cannot be maintained alongside other industries. The over-all value to the country over many years is the salient consideration. For some of the problems now facing the biologists and administrators there was no advance warning and scientific information to solve them was lacking. In time it will be obtained. Meanwhile the resource should be given protection lest it be irretrievably lost. Its present value and significance does not necessarily indicate its future worth.

Economics cannot be disregarded and the issue will be decided in part by how badly and by how many the continuance of the resource is desired. Implementation of large-scale plans will cost money and be subject to continual appraisal of the balance between expenditure and anticipated benefit. The outcome will also be determined, however, by the imagination, knowledge and wisdom of those who are entrusted with the trials and privileges of research and management. On these perhaps stringent terms we can have salmon for long years to come.

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DISCUSSION

DISCUSSION LEADER SARGENT: Dr. Foerster, those of us who come from the East, particularly the Northeast, are pleased to hear that you are not at present faced with a serious pollution problem. That is, we feel, one of the principal causes of our dilemma here in the Northeast.

You mentioned the matter of predators with respect to salmon, and I recall with respect to Atlantic salmon, that the question of predators also was considered important, and in that case it was mergansers. I have two questions. What are considered the principal predators of the Pacific salmon? The other one is a puzzling one to me, and that is the matter of any kind of predator control. I always feel that the predators were always there even when the fishery was in the virgin state, and unless the predators have grown for some reason that we do not understand, I wonder how much monkeying around we should do with predators.

DR. FOERSTER: You have brought up a very interesting subject, Mr. Sargent, and I wish I had time to argue it out rather fully.

With reference to your first question, fortunately our predators are essentially fish. Many of them are squaw-fish, which is not a commercial fish in British Columbia and is discarded even by anglers. We know that trout are very active predators, and we are continually running up against the opposition of sport fisherman to the removal of trout. I feel, however, that if the sport fishermen could only keep the trout populations under control and could keep them down to a sufficiently reasonable level, we could still have trout and salmon as well.

That is a problem that is facing us at the present time. We are trying to see if we can't arrange some compromise whereby we can let the sport fishermen have their trout and also allow a good production of salman. In one test where sockeye are being studied, we have found that of the trout population, the fishermen are actually taking about 10 per cent of the total population of trout. Is it necessary to have such a backlog of trout to meet the needs of the trout fishermen?

With reference to the other question, these coarse-fish predators have always been there. We take the attitude that they have always been there and we still have quite adequate salmon populations, but the salmon populations are being

cut down by at least 50 per cent if not greater. The coarse fish have been allowed to boom up; whereas the salmon are under pressure continually in trying to maintain themselves.

I perhaps am not as concerned about attempting to remove predators. I don't see why we can't keep them under control. But, if by a minimum of effort we can cut down the numbers of predaceous fish, I am sure that the increased production of salmon would more than make up for the expenditure involved. That, I think, is what Dr. Neave means by semi-cultivation; just a small effort at removing predators might have a very good effect in producing more salmon.

MR. B. UREN [Ontario]: Have you had any problems with DDT spraying, and if so, has it had any effect on the population?

DR. FOERSTER: To my knowledge, heavy DDT spraying was only done in one area of the British Columbia coast a few years ago. We knew nothing about it until we saw it in the papers, and immediately, of course, we began to worry about the effect on the salmon.

While we were not able to make adequate tests, nevertheless we sent a chap over to see just what effect it might have had on the young fish. The evidence we got at the time was that the spraying was too extensive, and perhaps the salmon streams involved were too few, to give us anything definite. I think the department involved at that time in the spraying realized its mistake. We were told the next time they try it, we will be advised so that we can make tests of the effect.

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GROUNDFISH STOCKS OF THE WESTERN NORTH ATLANTIC[1]

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INTRODUCTION

This paper gives an account of some of the chief groundfish populations of the Western North Atlantic and discusses the status of the stocks, some exploratory efforts, and the conservation of these fish stocks.

The area under discussion is the Western North Atlantic from West Greenland to south of Cape Cod at Latitude 39°00'N. The divisions mentioned are the Sub-areas 1, 2, 3, 4 and 5 of the Northwest Atlantic as defined by the International Commission for the Northwest Atlantic Fisheries (ICNAF), Figure 1.

The Canadian groundfish catches include the Newfoundland catches. Cod, haddock, redfish, American plaice and halibut populations, only, will be considered. There will inevitably be somewhat more data and greater coverage from the central areas which are best known to the author.

It is not convenient to give in each case the sources of the statistics

[1]In the absence of the author this paper was read by Dr. J. L. Kask.

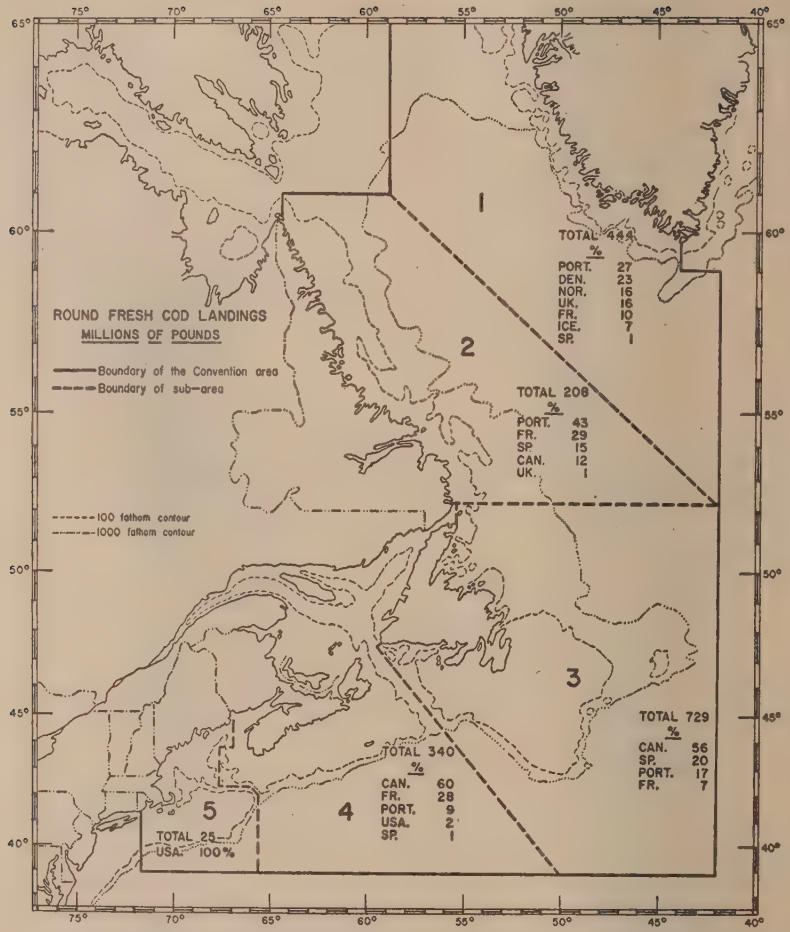

Figure 1. Total landings of fresh round cod from each sub-area of ICNAF in 1953 and the percentage in each sub-area captured by each country. (The catch of a country obtaining less than one per cent of the catch in a sub-area is omitted. Only the southern part of the Greenland sub-area (1) has been shown, although the whole reported cod catch in Sub-area 1 has been included. Catches by Italy of 19 million pounds from sub-areas 3 and 4 are not included. About 11 million pounds caught by St. Pierre and Miquelon, presumably in sub-area 3, are not included in Figures 1 and 2. The data used are the latest available, but are from ICNAF mimeographed data and while generally correct may not be in their find form).

quoted, but the chief sources have been the many unpublished, mimeographed papers prepared in recent years by or for ICNAF, 1952-54, and in addition Sette (1928), Needler (1930a), the statistical portion of the Second Annual Report of ICNAF (1952) and Statistical Bulletin, Vol. 2 of ICNAF (1954).

In addition to the countries mentioned elsewhere in this paper and in Figure 1, a small amount of fishing has been carried out in recent years in the ICNAF Area by Germany and Russia.

The cod and the haddock populations in different sub-areas have been shown to be essentially separate and distinct. (Cod: Schmidt, 1930; Schroeder, 1930; Thompson, 1943; Hansen, 1949. Haddock: Needler, 1930b; Vladykov, 1935; Thompson, 1939.) The few individuals that pass the deep-water barriers between sub-areas are insufficient to change in any measurable way the racial characteristics or abundance of the sub-area populations. An exception must be made for Sub-areas 2 and 3 between which there is no barrier except that of distance and where there is evidently more intermigration of cod than between the other sub-areas. The west coast of Newfoundland section of Sub-area 4 also has a stock of cod, a large part of which spends the winter in Sub-area 3 and some part doubtless also in Sub-area 2. Only a small proportion of Sub-area 4 cod, however, are caught on the west coast of Newfoundland.

Redfish populations apparently migrate little and for both redfish and American plaice, although no tagging has been done on redfish and little on plaice, evidence from size at sexual maturity and from other phases of the life-history indicate no very significant degree of movement between sub-areas. Probably in redfish there is some movement in the deep water between sub-areas, but if such movements exist they are unlikely to be great enough to render invalid conclusions regarding trends of catch within sub-areas.

Cod

Exploitation. By far the greatest fishery in the ICNAF area is for cod, *Gadus callarias*. The cod fishery in the Northwest Atlantic began very shortly after Cabot's discovery of Newfoundland in 1497 and has continued for more than four hundred years. Traditionally from the beginning, the fishery has been an international one in the Newfoundland area, Sub-area 3 of ICNAF, which is the greatest cod area. The fishery is also international in Sub-areas 1, 2 and 4. In Sub-area 4 Canada obtains the greatest share of the catch (60 per cent in 1953). In this year France obtained 28 per cent of the catch in Sub-area 4. In Sub-area 5 almost the whole catch is taken by the United States.

At the present time the most important cod fishing countries of the western North Atlantic area are Canada, Portugal, France and Spain. The total of the cod catches by other European countries fishing in this area, namely, Denmark (including also West Greenland and the Faroes), Norway, the United Kingdom, Iceland and Italy, is rapidly increasing.

The total cod catch for the whole area has averaged more than 1,850 million pounds per year from 1950 to 1953.

Over the ICNAF area as a whole from Greenland to Cape Cod the cod catch has been increasing considerably since the early 1930's, and there has been a considerable increase since the end of World War II after a decrease in effort and in catch during the war. There is as yet no indication that the catch of cod in the area has reached its peak. Traditionally in Sub-areas 2, 3 and 4 Canada has caught by far the greatest amounts of cod. The Canadian proportion of the catch, however, has been decreasing and that of the European nations increasing (Figure 2). This has partly been due to the increased catches in Greenland, almost entirely by European ships, but also there has been a decreased Canadian catch relative to the European in Sub-areas 2 and 3. From lack of statistics on the European catch in Sub-area 4, the proportions of the catch caught by European and by North American fishermen in this sub-area are in doubt except for 1953. The United States cod catch has decreased very greatly since 1880 when many of her dory-vessels fished for cod on the Grand Bank and other northern areas.

The total catch and the percentage of the cod catch in each sub-area obtained by various countries in 1953 are shown in Figure 1.

In the northern Sub-areas, 1 and 3, West Greenland and Newfoundland, respectively, there is as yet no indication of overfishing for cod, and the Labrador area, Sub-area 2, is almost certainly underfished for this species.

In Sub-area 4, the Nova Scotian Banks and the Gulf of St. Lawrence, the larger part of the catch (60 per cent in 1953) is obtained by Canada. In this area there has been some decline in Canadian and U.S. cod catches in recent years from peak landings in 1945-46 and the proportion of large cod in the landings has decreased. The available statistics of catch and effort, however, are for too short a period and the data on the European catch in Sub-area 4 is too incomplete to indicate clearly a depletion in the cod population. The 1953 statistics, which for the first time show the apparently large (28 per cent in 1953) catches by France in Sub-area 4 leave us in doubt of the magnitude of the downward trend and render it imperative that

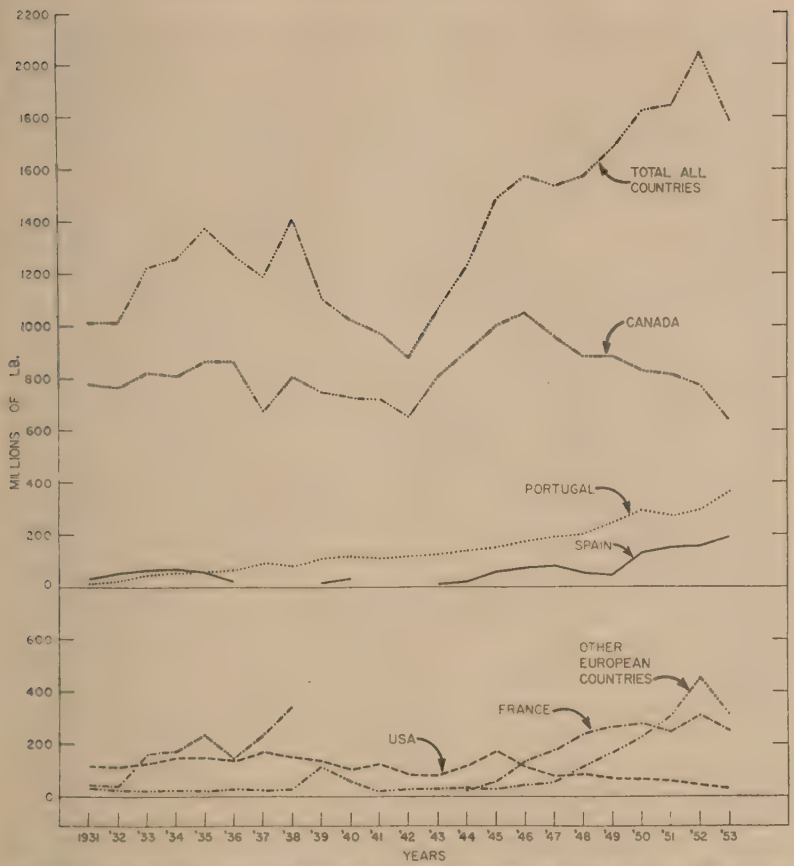

Figure 2. Landings in millions of pounds of round fresh cod, from all five ICNAF sub-areas, 1931-1953. ("Other European countries" include Denmark, Norway, United Kingdom, Italy and Iceland.)

attempts be made to obtain better sub-area statistics and to ascribe past catches, if such is possible on the basis of existing information such as vessel logs, to the appropriate sub-area.

In Sub-area 5, including Georges Bank and most of the Gulf of Maine, and fished entirely by United States vessels, the cod landings have decreased gradually since 1930 and more rapidly since 1946. It does not appear to be certain whether this decrease is a natural one or whether it resulted from a decrease in effort by line vessels specifically directed toward cod, with an increasing proportion of the effort

by trawlers devoted to catching haddock and redfish. There is a possibility that the decrease is due to increasing water temperatures which in the long run are unfavorable to the cod near its southern limits, but this should not be too readily assumed until the question of the diversion of effort from cod grounds and from methods such as line fishing, especially suited to cod, is examined closely.

Exploration. It would seem to be almost an impossibility, after four centuries of intensive exploitation by many nations, that any large unfished grounds and virgin stocks of cod remain in the Newfoundland area. Such fishing grounds and stocks, however, have been discovered recently. During its long history, the Newfoundland shore fishery for cod has been typically a fishery of the very shallow waters. The cod, attracted to the very shore by the onshore spawning migration of the capelin, are readily captured in June in 5 or 10 fathoms and progressively deeper as the summer and autumn advance. These inshore cod are generally small and young. The usual gear has been the trap, the handline, and the longline pulled by hand.

On the northeast coast of Newfoundland where these inshore cod are so abundant, fishermen in the main cod-fishing areas, which are near the headlands, have occasionally tried fishing a short distance outward from their regular fishing grounds and finding cod scarce or absent proceeded no further. Their small boats of 30 feet or less in length were unsuitable for offshore voyages and their gear was unsuitable for deep-water fishing. They also had a firm belief that there were no cod available beyond the immediate inshore area. Their fishing was thus restricted to the fishing grounds out to about six miles offshore. Here the cod were typically small, and there were violent fluctuations in numbers.

By its exploratory work since 1950 the Department of Fisheries of Canada working through the Fisheries Research Board and the Board's Newfoundland Fisheries Research Station has changed completely the mental outlook toward this fishery.

Using 55-foot longliners with longline gear worked by mechanical gurdy, the area from 10 to 40 miles offshore has been explored systematically. In the area along the northeast coast of Newfoundland and extending northwards to Labrador the coastal water deepens rapidly to 150 fathoms or more. The Labrador Current hugs the coast and is deepest near the coast. This current has a central core of cold water usually −1.0 to −1.5 degrees centigrade or even lower in temperature and extends in the early spring from the surface to 120 fathoms or deeper. In late spring and early summer the shallow layers warm up and the traditional early summer fishery is for small

cod which follow the capelin into this shallow layer of newly warmed water.

In this northern region the bigger and older cod do not usually come inshore, but remain, where all the cod both large and small have spent the winter, in the deep water typically below 120 fathoms. This deep water is Atlantic water connected with the deeper waters of the Atlantic Ocean and is warmer and saltier and heavier than the more superficial waters of the Labrador Current.

These large cod were found to be very abundant in the water near and below the depth where the lower border of the below 0 degrees centigrade layer meets the underlying warmer deep Atlantic layer. Once this relationship had been determined by experimental fishing off Bonavista in 1950 and 1951 the search for deepwater cod was concentrated along the deeper borders of the Labrador Current mostly 10 to 60 miles offshore and abundant supplies of large cod were found. Thus new fishing grounds with abundant large cod were found along a several-hundred-mile stretch of coastal shelf from Trinity Bay to Southern Labrador. Except in a very few places where the deep water came very close to the coast or where, farther offshore, European trawlers had made an occasional set, these deep-water cod had not been fished. The best of the new fishing grounds, which were in deep water 20 to 60 miles off bold headlands, had apparently never been previously fished.

Here was a great reserve of large cod which, as they grew older and larger and became less and less likely to visit the shallow water, were relatively safe from the effects of the fishery.

A new fishery by mechanical longline is rapidly developing for these large cod, and these newly discovered grounds and cod populations appear likely to be able to provide a catch of over a hundred million pounds of large cod per year.

REDFISH

Exploitation. The North American fishery for the redfish, *Sebastes marinus,* began to increase rapidly in 1935 when 17 million pounds were landed in the United States as compared with less than 2 million pounds in 1934 and less than 300,000 pounds in 1933. The redfish fishery is in deep water and until recent years has been almost entirely and even now is chiefly prosecuted by United States vessels. The chief area fished at first was the Gulf of Maine but there were some catches on the Nova Scotian Banks. As the local supply became reduced the American fishery on the Nova Scotian Banks increased and gradually spread northward.

From the Fisheries Statistics of the United States (1954) the record American redfish catch of 258 million pounds was obtained in 1951. For the whole Western North Atlantic the highest catch was about 298 million pounds in 1951. Eighty-seven per cent of this catch was by U.S. and almost all the remainder by Canadian vessels. The catch in 1953 was about 230 million pounds. The landings are declining in Sub-area 5 and in the Nova Scotian Bank areas of Sub-area 4, and redfishing is gradually spreading northward. This involves the building of larger and faster redfishing vessels by the United States, to fish the Gulf of St. Lawrence and the Grand Bank areas. Beginning in 1953, the redfish in the West Greenland area, Sub-area 1, began to be exploited in quantity, particularly by Icelandic trawlers.

Exploration. Since 1947 the fisheries research ship *Investigator II,* operated by the Newfoundland Station of the Fisheries Research Board of Canada, has explored the abode of the redfish in the deep water between 100 and 400 fathoms. Some large virgin populations of redfish were found in the Gulf of St. Lawrence, on the South Coast of Newfoundland, on the southwestern and the eastern Grand Bank, on Flemish Cap, north of the Grand Bank and east of Hamilton Inlet Bank in Labrador.

In the warmer more southern parts of the area, such as on the southwestern slope of the Grand Bank, redfish are plentiful from 80 to 200 fathoms, while off Labrador commercial quantities occur only deeper down, from about 160 to 300 fathoms. The northern redfish are considerably larger than the southern and the deep water redfish are larger than those of the shallow water.

In the past few years Canadian trawlers have begun to exploit in quantity these newly discovered redfish populations and American trawlers also have moved into the Gulf of St. Lawrence and to the Grand Bank areas and are landing yearly from these areas a catch several times as great as the Canadian catch. The redfish populations off the northeast coast of Newfoundland and east of Hamilton Inlet Bank have not yet been exploited commercially.

AMERICAN PLAICE

There is a small fishery for American plaice, *Hippoglossoides platessoides,* in the New England area, Sub-area 5. This is of the order of three or four million pounds yearly. The American plaice, however, is more abundant in colder water in the northern Sub-areas 3 and 4.

In the Newfoundland area, Sub-area 3, the fishery for American plaice has developed rapidly within the past few years from a catch of less than half a million pounds previous to 1948, to about 30 million

pounds a year in 1951-53. Almost all this fishery is on the eastern and northern Grand Bank. Also in the Nova Scotian and Gulf of St. Lawrence areas, Sub-area 4, the catch of plaice has increased from two to three million pounds a year previous to 1948, to about 15 million pounds a year in 1952 and 1953. About 12 of these 15 million pounds were caught on fishing grounds of the Gulf of St. Lawrence which are in the northern colder water parts of the southern half of the Gulf.

The plaice is abundant and large in the very cold-water areas with bottom water close to 0 degrees Centigrade for most of the year. The Grand Bank areas were discovered largely through the efforts of the *Investigator II* and of Newfoundland otter-trawlers.

The Gulf of St. Lawrence fishery for plaice developed with the recent introduction of large numbers of small 55-60 foot otter-trawlers particularly in the Caraquet area of northern New Brunswick.

The *Investigator II* has found a small area on Hamilton Inlet Bank in Sub-area 2, where American plaice are plentiful, but as yet there is no commercial fishery for plaice in Sub-area 2.

It is a little uncertain at the present time whether or not the catch of American plaice in Sub-areas 3 and 4 is reaching its peak. Doubtless a greater quantity could be caught, at least for a few years, by more intensive fishing.

HALIBUT

The Atlantic halibut, *Hippoglossus hippoglossus,* is less abundant than its Pacific relative *Hippoglossus stenolepis.* On the Atlantic Coast most of the halibut catch is landed by vessels using longline fishing gear. Quantities are, however, landed by otter-trawlers, particularly from the warmer slopes of the banks. These otter-trawl fish are mostly small, young halibut caught in shallower water than the line-caught larger halibut. European vessels fishing in the slope areas of St. Pierre, Green and Southwest Grand Banks for cod and haddock for salting, must catch considerable quantities of these halibut and usually discard them.

Although of lesser magnitude than the halibut population on the Pacific Coast, the halibut catch in the ICNAF area on the Atlantic Coast of North America and West Greenland might be one-quarter to one-third that on the Pacific Coast if protection could be given to the young fish. The United States catch alone was 20 million pounds gutted weight in 1896 and was over 10 million pounds in each of the years 1893 to 1900. Even in 1921 the United States catch was 6 million pounds, while the United States catch per year, in recent

years, has been only about 400,000 pounds. The U. S. catches were made chiefly in Sub-areas 3, 4 and 5 of ICNAF and small amounts were taken, in the earlier years, from Sub-areas 1 and 2 and even from the Iceland area. A considerable decrease would have occurred in any case but the rapidity and extent of the decrease has been largely due to the decline in the United States line fishery for halibut.

The Canadian halibut catch between 1933 and 1939 ranged between 3 and 5 million pounds head-off, gutted weight per year. In the period from 1940 to 1948 the average yearly catch was less than 2 million pounds. The low catch was due to reduced effort in halibut fishing during the war years. This led to an increase in weight of the halibut population, which when line fishing effort for halibut rose again, resulted in a catch of over 10 million pounds in 1950, 8 million in 1951, five and three-quarter million pounds in 1952 and 6 million pounds in 1953.

The United Kingdom landed over 11 million pounds of gutted halibut from the Greenland area (Sub-area 1) in 1929, 9 million pounds in 1930, 11 million in 1931, and over 5 million pounds, mostly from Sub-area 1 with smaller amounts from the Labrador sub-area, in each of the years 1928 to 1935. The United Kingdom halibut catch had fallen to 700,000 pounds by 1938.

At present European countries land small amounts of halibut almost entirely from the Greenland area. Complete statistics are not available but the European catch in Sub-area 1 in 1953 was approximately two and a half million pounds.

HADDOCK

There are three large and essentially independent groups of haddock populations on the North American Banks. These have their main winter and spawning abodes on Georges Bank, the Nova Scotian Banks and on the Newfoundland Banks respectively. These main population groupings, each of which in the two northern sub-areas, at least, includes some relatively independent sub-groups, are separated by deep channels.

The New England stock in Sub-area 5 is caught entirely by American vessels and had a peak catch of 278 million pounds of round fresh haddock in 1929. During the past 20 years the catch has stabilized at about 100 to 120 million pounds per year.

The landings of haddock in the Nova Scotian area, Sub-area 4, reached their peak in 1935 when the landed catch in the United States and Canada from this area was 148 million pounds of round

haddock. In 1953 the catch was about 100 million pounds, approximately the same amount as in the New England area. In 1953 Canada obtained 56 per cent of the haddock catch in Sub-area 4, the United States 43 per cent and Spain 1 per cent.

Haddock populations on the Newfoundland Banks, Sub-area 3, were first explored by the research trawler *Cape Agulhas* of the Newfoundland Fisheries Research Station in the years 1931-35 (Thompson, 1939). Haddock fishing on these banks was negligible before 1946 and the peak catch was in 1949—about 150 million pounds of round fish. Since that year there has been a decline in the catch which in 1953 was 77 million pounds. Omitting other countries which land only very small amounts of haddock, in the 10 years between 1944 and 1953 about three-quarters of the haddock catch in the Newfoundland area (Sub-area 3) was landed by Spain and one-quarter by Canada. In 1953 in this sub-area, Spain obtained 58 per cent and Canada 40 per cent of the haddock catch.

CONSERVATION

Cod. In considering the general picture of these great fisheries for groundfish in the entire ICNAF area, it is obvious that the cod fishery, after more than four centuries of heavy exploitation, shows by far the greatest resilience and ability to withstand a very heavy fishery. The actual and the potential volumes of production are also apparently very much greater for the cod than for the other groundfish.

There are many features favoring the abundance and survival of cod in the area under consideration. The cod has equally projecting upper and lower jaws and can feed at will on the bottom or in midwater. It can range and feed from the surface to 200 fathoms although it is normally not plentiful below 160 fathoms. With its wide vertical and horizontal range the cod can accommodate itself also to a wide range of temperatures.

In the northern sub-areas the great abundance of the plankton feeding and pelagic capelin, *Mallotus villosus*, provides vast quantities of cod food and is the greatest single food factor in the maintenance of the great mass of the enormous northern cod populations. As the cod grows older and larger it favors deeper waters where it is not so readily fished. While, if food is plentiful, it may at times be present over any type of bottom, the cod, especially at the larger sizes, favors rough rocky bottom which is not readily trawled. In the adult stages cod migrate far and change their abode rapidly. In the colder areas the cod may spend a month or more, during and after spawning, largely in the upper layers of water where they are not available to

ordinary otter-trawl gear. The greater and more northern portion of the cod population cannot be fished in the winter and early spring. The cod grows rapidly to a large size and this reduces the number of predatory enemies. Over most of its range, neglecting the relatively scarce sharks, the cod is the dominant large fish. The presumably predatory pollock and silver-hake and young dogfish generally live south of the main cod areas. The cod is not purely a bottom fish and the younger stages are typically farther above the bottom than the larger fish; consequently the destruction of young cod by otter-trawlers is not generally nearly as great as with young haddock. (There are some exceptions to this statement in certain shallow-water bank areas where young cod are abundant.) By far the greatest factor, however, is probably that especially in the northern Sub-areas 1, 2 and 3 of ICNAF, Greenland to Newfoundland, the rough bottom and the very large area covered by low temperature water of minus 0.5 degrees to 3 degrees centigrade favor the cod more than any other groundfish and render more likely its survival on settling from the pelagic post-larval stage. The large expanse of suitable area also, probably close to 100 thousand square miles in Sub-area 3 alone, renders failures of year-classes unlikely and unusual in this central part of the cod range. Also the inshore waters of the east coast of Newfoundland are nurseries for young cod and the shoreward set of the Labrador Current in this area ensures an abundant supply of young cod to settle in these favorable waters. To the northward, however, in the Greenland area there are great fluctuations in year-class survival.

While, doubtless, the cod population could be managed for greater economy of effort and the sizes at capture could be increased and while through natural changes in the sea environment or through very greatly increased exploitation the situation could change rapidly, there is at present no obvious need for repressive efforts to protect cod from over-exploitation in the three northern sub-areas. The situations in the New England area and in the southern Nova Scotia area are more uncertain and should be studied carefully. A number of essentially separate populations of cod, however, exist in the northern sub-areas as well as in the southern. In Sub-area 3 for example there are at least three essentially separate populations. Some of these populations may be over-exploited while others are under-exploited and the total for the whole area or sub-area may not reveal the true picture. It is wise, therefore, to study in detail each population and the effects of the fishery on it. Many countries are carrying out studies on various populations of cod in the ICNAF area.

Redfish. The redfish is a very slow-growing fish, attaining in many

areas a size of less than 10 inches in 10 years (Perlmutter and Clarke, 1949). It is usually fished over very rough bottom, in deep water on the slopes of the banks. It is landed round at a low price, and to produce a paying trip, redfish must be caught in large quantities per day's fishing. This species, because of its slow growth and concentrated abundance in very narrow slope areas, suffers quickly under intensive fishing and each new population fished is quickly reduced in numbers. Only recently has very much been discovered on the life-history of the redfish and even now the information is so recent that most of it is unpublished.

The slow-growing redfish forms a concentrated fringe on the slope areas especially on the seaward edges of the banks and in deep depressions and channels. In all these situations it can readily be found and fished in quantity. From its slow growth and concentration and relative lack of migration it is probably continually in danger of being overfished, and once overfished recovery is bound to be slower than in the case of the haddock or cod. At present prices, however, the depletion is likely to be usually more economic than biological, since, especially in distant waters, redfishing must cease when heavy concentrations are no longer available. At this population level the redfish will still have great reproductive potential.

The redfish feeds on pelagic organisms and in Europe has been caught on longlines over very deep water. Thus, there is the possibility that there are great pelagic populations of redfish, generally unrelated to the bottom, of which the schools presently fished are only a fringe where the pelagic populations impinge on the slope areas. Apart from larval distribution, (Taning, 1949), however, there is no evidence as yet for the Western Atlantic that these great pelagic populations exist. The evidence from the experimental fishing of the *Investigator II* in deep water between 200 and 400 fathoms has been opposed to the existence of large pelagic populations of redfish. Also the quick decline in the catch per unit of effort and in the abundance of the larger sizes of female redfish in the newly fished redfish populations of the Grand Bank and other areas, does not give any indication of replenishment of exploited slope and bottom related populations from pelagic populations. The question, however, needs much more research before an adequate answer can be given.

Suitable methods of protection which will also allow a large and profitable fishery for redfish to proceed are not yet obvious to the fisheries scientist. Mesh regulations may be possible but there are considerable difficulties. Among these are the traditional practice of capturing and filleting redfish down to a very small size and the spiny

nature of the redfish which causes them to mesh readily. The very slow growth of the redfish, if natural mortality is at all large, may prevent increase in population mass from the smaller to the larger sizes at present utilized. Also, owing to the limited fishing period per day (usually in daylight only), the low price of redfish and the practice of landing them round, it is necessary to catch redfish in large quantities per hour's fishing. Thus a mesh which would liberate a very significant portion of the catch might be uneconomical. On the other hand, on some fishing grounds there might be some increase in efficiency from the larger mesh. Also in many areas during certain months at least commercial quantities of larger redfish may be obtained by fishing more deeply.

American plaice. The very slow-growing American plaice is a bottom-living species, readily caught by otter-trawlers. In northern areas it is especially related to water of about 40 to 120 fathoms in depth. In the most heavily fished plaice areas the bottom is moderately smooth. Also on the Grand Bank, at least, a considerable reserve of plaice exists where the bottom is rough and the plaice population apparently is less concentrated and less available to trawlers.

The plaice in their cold water areas of abundance, in Sub-areas 3 and 4, grow to a large size but are also very slow-growing. In the commercial catches from the Grand Bank (according to Mr. R. S. Keir's age determinations at the Newfoundland Fisheries Research Station), plaice are on the average more than 20 years of age.

These concentrated populations of plaice are newly fished, slow-growing, and readily exploited from their consistent location on or near the bottom in the same areas. The fishery is too new to supply adequate evidence on whether or not the catch has reached its greatest yearly amount and what the maximum sustained yield will be. It is to be expected, however, that a considerable reduction will occur in the catch per unit effort and in the total catch when the accumulated virgin stocks of plaice are reduced by the fishery to the point where the catch must depend on the annual growth of the plaice population.

There is at present no specific plan for protecting American plaice in the ICNAF area. The 4½-inch mesh trawl-net regulations, if applied for cod, will in certain areas be a protection for young plaice. Owing to their preference for even lower temperatures than cod, quantities of plaice are encountered during many cod trips but not usually during haddock trips. For the same mesh size, due to the depth of the body in the plaice, the 50 percent selection point for plaice is at a considerably smaller length than for haddock or cod.

Halibut. The halibut of the Northwestern Atlantic live chiefly in

the waters of intermediate temperatures, particularly on the seaward slopes of the banks and in the deep channels. The deep-water distribution parallels that of the redfish which is one of the chief foods of the halibut (McIntyre, 1953).

In some parts of its distribution, the northern part of the Gulf of St. Lawrence, on the southwestern portions of the Newfoundland banks, the east coast of Nova Scotia and where warm water impinges on the slopes of the banks, much of the halibut population in spring and summer moves into shallower water near the slopes of the banks or inshore. Elsewhere as on the east coast of Newfoundland and Labrador, where there is a barrier of below 0 degrees centigrade water, the halibut remain throughout the year in deep water, usually more than 120 fathoms, and do not approach the shore.

A great deal of otter-trawling for other species occurs on the slopes of the banks and young halibut are particularly vulnerable as incidental catches in these fisheries for cod, haddock and redfish. These young otter-trawl halibut are doubtless caught many years before they have reached their best population weight for capture.

In the halibut areas of the Pacific Coast the halibut is the dominant large fish on the banks and otter-trawling of halibut is regulated to the advantage of the line fishermen. In the Atlantic area, however, the most important fishes on the banks near the halibut areas are the cod, haddock and redfish and the value of the halibut both actual and potential is not large compared with the value of the fishery for the other groundfishes. Up to the present time no good method has been found to protect halibut in the Atlantic areas where otter-trawling and line fishing for other species are greatly predominant. The present and the potential values of the Atlantic halibut fishery, however, are by no means negligible, particularly for Canada, since the landed value of halibut per pound is considerably greater than that of cod, haddock or redfish. In spite of the discouraging prospect of success, fishery biologists should occasionally try a little imaginative effort in search of ideas for the protection of the Atlantic halibut.

Haddock. Haddock grow rapidly in comparison with redfish and American plaice. They are, however, considerably faster growing in the southern part of their range on Georges Bank, than in the northern part, on the Newfoundland Banks. Haddock may thus enter the American fishery on Georges Bank at 16 inches in length and less than three years of age, while haddock of the same size on the Grand Bank and St. Pierre Bank are four or five years old. Each population has its own growth and survival characteristics and must be studied independently. Considerable yearly differences in the survival of

year-classes occur in all haddock populations. These fluctuations, while always great, are much more extreme in the northern than in the southern parts of the haddock range in the ICNAF area. On the Grand Bank and St. Pierre Bank the survival rate of one haddock year-class may be a hundred times greater than that of another. Under these conditions accurate long-range forecasting of haddock abundance is at present impossible. Short-range predictions, however, are being given by studying the abundance and growth of year-classes of haddock from about one year of age and older.

Compared with the cod, the haddock with its underslung mouth is much more closely related to bottom living and feeding and to occupancy of smooth bottom areas. All stages from one year of age and upwards are thus more vulnerable to destruction by otter-trawls than are the young of other groundfish species of similar age. In contrast with the cod where the greatest populations live beyond the influence of the Gulf Stream, all the major haddock populations of the Western Atlantic live and spawn on the northern edge of the Gulf Stream. Large eddies exist between the Gulf Stream and the haddock areas of the various banks. These eddies in certain years and months may suck off the water from the neighboring haddock areas of the banks. With the water, at any time during their several-month-long pelagic existence, the young haddock may be drawn off over oceanic areas with water more than a mile deep (Iselin, 1939). As in the European area, winds are doubtless of great importance in the northwest Atlantic in the movement to favorable or unfavorable environments of the superficial layers of water containing the haddock larvae (Carruthers, Lawford and Veley, 1951; Carruthers *et al,* 1951; Carruthers, 1951). In the New England area the widespread nature of the dispersion of haddock eggs and larvae and the importance of currents in producing this dispersion were shown by Walford (1938).

Inevitably, when several months after hatching, these young haddock settle to take on a bottom-feeding existence, they must perish if they are not over bank or slope areas preferably less than 100 and at the most about 150 fathoms. All this is somewhat hypothetical but very likely represents the actual case. The haddock in all areas of the Western Atlantic spawn near very deep water and it is unlikely that variations in food or temperature can account for such complete losses of haddock year-classes as occur in the Newfoundland region.

In addition to their dangerous spawning situation, the young haddock have the cod and presumably the pollock, silver hake and other fishes as predators.

In the New England area, Sub-area 5, an experiment on using

larger meshes in otter-trawls was begun in 1953, following advice from ICNAF. This and other measures of haddock protection were advocated much earlier by Herrington (1932, 1935, 1936 and 1941). It is hoped to prevent the killing of small haddock of sizes which were formerly thrown away at sea, and also to release for further growth some of the small haddock at sizes formerly landed. Thus it is expected that increases will occur in the landed size and in total landed weight. Since the larger fish are more valuable per pound, the values should increase also.

In Sub-areas 3 and 4, gear and population researches are in progress to study the biological basis for mesh regulations under ICNAF.

From the typically bottom abode of the young as well as of the older haddock a mesh regulation requiring a minimum inner wet measurement of 4½ inches in meshes of otter-trawls should assist the preservation of haddock much more than that of cod. In most areas a larger mesh than 4½ inches would probably be required to have a measurable effect on the cod population.

For areas and degrees of haddock abundance in which the slowing effects of crowding on growth are sufficiently small or not evident, it is possible to say that saving young haddock which are discarded at sea should represent in the future some increase in the landed catch. In the New England area, until recently, an otter-trawl cod-end mesh with internal dimensions of 2⅞ inches was used. It is possible for this area to calculate mathematically with some degree of confidence that the gain in weight by growth is probably greater than the loss from natural mortality at the sizes which would escape from a 4½-inch or even somewhat larger mesh (Graham, 1952). Thus it may be argued that greater total catches and larger more valuable fish will be landed by the larger mesh. The expected eventual increase in yearly landings for the Georges Bank area is about 30 per cent if the fishing intensity existing at the time of the change to the larger mesh is maintained (Graham, 1952). Graham and Premetz (1955) state, on the basis of the first year's experience with the mesh regulation and in the light of recent changes in haddock sizes exploited on Georges Bank, that the long-term increase is expected to be greater than 30 per cent.

There are, however, many more unknowns than knowns involved in the argument. There is first of all the fact that the large mesh will protect not only haddock but also cod, silver hake, small dogfish, small flatfishes and other species which either are predators on haddock or compete for food with them at some stage. The effect of the larger population of small haddock below the size of retention by the

large mesh, on the survival of members of still younger year-classes is unknown. Herrington (1944) has presented data supporting the idea that the presence of large quantities of older haddock is unfavorable to the survival to the scrod size of large numbers of young. It is also not possible at present to know either the total or the natural mortality rate in the youngest year-classes of haddock. A net, for example, with all its meshes so small that no one-year-old haddock can escape, will doubtless be very inefficient for capturing the larger sizes. Research vessels, also, are probably not numerous nor available enough to cover bank areas adequately for abundance studies. Thus mortality calculations for younger fish are projected back, probably incorrectly, from the older year-classes of haddock which are fully represented in the commercial fishery. While the total yearly mortality of the larger sizes can be estimated with some degree of precision, the natural mortality is in doubt at all ages but especially at the youngest and the greatest ages.

The large-meshed net is apparently more efficient for catching the larger fish (H. W. Graham, 1954, and Graham and Premetz, 1955) and thus while younger immature fish formerly caught are spared to increase in size, the older fish, from the smallest sizes fully retained, are under greater pressure and consequently should have a greater percentage total mortality than previously. Ships using larger mesh will, when it is economically worthwhile, deliberately fish for larger fish. Even when operating in the same very large and concentrated schools of small haddock as presently exist on the Newfoundland Banks, large-mesh trawlers pull the net for a considerably longer period for each set and doubtless per day's fishing than the trawlers using small mesh. Since the large-meshed net also should move somewhat faster for the same power expenditure and strain water more readily so that less water is pushed ahead of the net, it is inevitable that more fish, of the sizes fully retained by the large-meshed nets, will be caught per day's fishing by the large-mesh than by the small-mesh trawlers. Even the larger sizes below those fully retained by the large-meshed nets should show increased capture rates. If there is an increase in size and numbers and consequently value per trip, the fishing pressure will increase to reduce survival and size (M. Graham, 1954). These situations may be unfavorable only at sizes and ages where the total weight of the population is still increasing rapidly and may be favorable if an age has been reached where natural mortality equals or exceeds increase in weight by growth.

It is becoming apparent that in the Newfoundland area, where the extremes of hydrographic conditions may often concentrate haddock

in dense schools over comparatively small bottom areas, the possibility cannot be overlooked that crowding retards growth. It is quite possible that similar crowding effects may be present in the cod of the Greenland and the Labrador sub-areas. Where such crowding is extreme the use of the large-meshed net and the saving of small haddock, whether previously discarded or retained, may not produce the expected benefits.

Since the older fish, with very much greater numbers of eggs per fish than younger fish, are being reduced in numbers faster by the more efficient large-meshed net, and the younger fish saved to grow toward maturity, it is uncertain whether or not the total number of fertilized eggs produced by the haddock population will be increased by the large-meshed net. Many biologists will argue that within very large limits the size of the spawning population is of little or no importance. Experiences with Pacific salmon, however, show that while percentage survival of young is greater with small spawnings the total survival is greater with large spawnings, although with still larger spawnings there may be some reduction in total survival of young (Ricker, 1954). With the tendency toward destruction of new haddock year-classes before settling, it may well be important that haddock should spawn in as great a quantity as possible, and especially over as great an area as possible. The latter is obviously more likely to occur when the spawning population is large. Thus the chances are increased that at least some fringes of the floating young will settle in suitable depths and locations.

The institution of a larger mesh on otter-trawls, for groundfish populations with suitably fast growth in relation to the natural mortality, is very likely a step in the right direction but it is not necessarily the only step to be taken. At present it is best to regard the institution of a larger mesh size as a very worth-while and long-range experiment, which, with all the variety in natural survival of young haddock and of fishing intensities, will take many years to work out. For a considerable time it will be unwise to allow other conservation measures to interfere with the assessment of the mesh experiment. In the Northwest Atlantic the best biological and statistical background for this experiment is for the haddock of the Georges Bank area. Since the area is fished by only one nation, the most complete biological and statistical data and the most efficient control of the enforcement of the mesh regulation should also be possible in this area. Proceeding northward there is less background data available and more nations involved in the cod and haddock fisheries. Thus there is much less likelihood for sub-areas north of Sub-area 5, that

if in the near future, larger mesh sizes are established by regulation, it will ever be possible to offer scientific proof of the value of the regulation.

It would be preferable that one sub-area be left without mesh regulation, or even better, to have the fishery in one sub-area deliberately carried out by the usual type of small-meshed nets, so as to serve as a control to the large-mesh experiment. This, however, may not be possible since ships in one trip may fish several sub-areas and difficulties of law-enforcement arise.

Climate. Over and above all the considerations discussed is the overriding effect of climate (Rapports et Procès-Verbaux, 1949). Increases in sea temperatures in recent years are credited with the great increase in the cod population in the Greenland area (Jensen, 1939; Dunbar, 1951; Tåning, 1953). Warmer water species such as billfish and mackerel have recently shown a phenomenal increase in the Newfoundland area (Templeman and Fleming, 1953). Recently, pollock have very greatly increased in numbers in Sub-area 3. Sea temperatures have increased, also, in the New England area (Taylor and Graham, 1953) and decreases in cod abundance in the southern part of the ICNAF area may be a response to warming waters. By the same token, if water temperatures increased more, it is possible that on the Newfoundland Banks the haddock population and the area populated by haddock would increase, and the cod population in the whole northern area shift slightly northward. The higher temperatures, however, will also increase, in the northern haddock areas, warm-water predator or competitive species such as pollock, silver hake and dogfish but decrease the predator cod. The resultant effect on the haddock population cannot be predicted adequately.

Slight increases in temperature might favor the growth of the American plaice of which the great commercial populations are in cold waters near 0 degrees centigrade. The lack of large American plaice populations, however, in the New England and the Nova Scotian Bank areas and in the relatively warm Southwest Grand Bank area indicates that a very few degrees temperature increase would probably render the present plaice areas unsuitable for maintaining large populations of plaice. Other flatfish species with higher temperature requirements—the winter flounder and the yellowtail flounder—would increase in numbers in Sub-area 3.

Particularly at the northern and southern extremes of the range of a fish, water climate and natural fluctuations in survival of young have usually much more influence on fish numbers in the sea than any interference by human efforts. Our reasoning regarding the effects

of mesh and other regulations on the fisheries is based on environmental conditions remaining approximately the same. Unfortunately for our ability to reason accurately in these matters, climatic conditions change continually and at present unpredictably. Continual routine hydrographic observations at the same stations in the fishing areas are a necessity and the biologist must do what he can to understand and assist nature in relation to fish populations. He must be wary of a typical device by which the usefulness of regulations is shown. A common method and often the only safe one politically is to make a regulation at a time when through natural fluctuations or for economic reasons the catch is low and then attribute to the regulation the increase in catch which is inevitable in any case. Fisheries regulations should usually be regarded as experimental. They should be as few as possible. It is my opinion that the fisheries biologist should not as a rule recommend an important fisheries regulation until a serious effort has been made to provide the essential background by which the effect of the new regulation may be assessed.

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DISCUSSION

DISCUSSION LEADER SARGENT: Having served with you, Dr. Kask, on the International Commission, I feel that you have presented a very long and difficult problem in a very brief period of time.

I wonder if you would care to comment on the question of climatic change as respects the fishery on the banks of Newfoundland. We understand the cod fishery of George's Bank, off of New England, has decreased presumably because of the warming of the waters. Likewise, we understand very definitely that the hatch has been increasing off the West Coast of Greenland where there was formerly virtually no cod fishery at all, and I wonder whether there has been a noticeable change of the current population on the Grand Banks as a result of this climatic change.

DR. KASK: I would like to refer to that very interesting development. Most of us think of climatic changes as taking great, great lengths of time. Most of us,

I think, are not too much concerned with being overtaken by a new Ice Age. But during the lifetime of most of us in this room there has been a marked change in the climate of this Northwest Atlantic area. The Sub-Arctic area has been progressively warming up. Although the effect on land and real estate is not so great and although people in the northern climate still believe their climates are getting a little warmer or better, but a change of a fraction of a degree in the temperature of the sea makes an enormous difference in the distribution of fishes.

Distribution of these ground fishes has changed quite materially in the last couple of decades. The New England banks are now almost entirely haddock banks because the haddock like warmer water than do the cod. The haddock migrated off George's banks and have been caught on Nova Scotia banks. Areas west of Greenland are now the scenes of active and large cod fisheries.

The haddock that Dr. Templeman reviewed in his paper—haddock catches being made on the Newfoundland banks are relatively new, because with this warming up of Arctic and Sub-Arctic waters—the haddock have moved from the southern areas on to these more northern ones and are producing sizable fisheries there.

Marine Biology and Oceanography, pp. 68-73. Pergamon Press Ltd., London.

Water replacements and their significance to a fishery

By H. B. Hachey
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ry—Attention has been directed to some of the major and more apparent effects that water nents may have on various fisheries. It has been indicated that such interchanges may be ible for the destruction of a fish population or the extension of others. The loss of larvae to and haddock areas has been considered as the result of movements of a water mass, and it is ed that the availability and catchability of certain species is effected by certain water replace- henomena. When consideration is given to the cycle of life in the sea, it will be quite evident ny indirect effects may follow from these water replacements. While the processes of long- placements are not too well understood, wind action is one of the more apparent major casual in short-term replacements.

INTRODUCTION

THE changing characteristics of a water mass, such as temperature and salinity, lowed in detail in the study of a fishery, the replacement of one body of water by er is a process which, generally, only attracts attention when the characteristics water bodies concerned are in considerable contrast.

ether it be of the estuary, a coastal area, or the open ocean, the particles of a mass are never at rest, being subjected to the internal and external forces of y, pressure, wind, tide and the Coriolis force. The resultant movements of the particles under these forces bring about the flushing of estuaries, the replacement ter masses in a bay or coastal area, the removal of water masses from a fishing and the transportation of large masses of ocean water from one location to er.

flushing of estuaries has been given considerable attention during recent years, the need of considering the many problems of pollution. The principles derived such studies furnish an insight into the mechanism involved in the replacement ters in a comparatively small area, almost completely land-bound. In contrast, n an ocean-wide scale, Cooper (1954, 127), has called attention to the large ions in the phosphate content and biological productivity of the English Channel last thirty years. He seeks an explanation in the replacement processes involving plenishing of deep Atlantic water by potentially rich northern waters, these deep tic waters eventually upwelling to determine the nutrient supply of the coastal s of north-eastern Europe.

ention is directed herein to many of the direct consequences to a fishery of the us processes of replacement.

THE DESTRUCTION OF A FISHERY

ELOW and Welsh (1925) describe the disaster to the tilefish, which first came to in March, 1882, when multitudes of dead fish were observed floating on the ce between the latitudes of Nantucket and Delaware Bay on the Atlantic coast. area of destruction was at least 170 miles long by 25 miles broad, and covered ntire zone inhabited by the tilefish north of Delaware Bay. It is estimated that

at least a billion and a half dead tilefish were sighted. There is evidence to in that the destruction of this fishery was caused by a sudden temporary flooding bottom by abnormally cold water. It has been shown that the tilefish of the A coast occupies a very definite environment, for it lives only along the upper part continental slope where the water temperatures are approximately 10° C, and ventures into the lower temperatures on the shoaling bottom nearer land. We in BIGELOW and WELSH'S account of the disaster to the tilefish, a well-docun record of the significance of a temporary incursion of waters of contrasting ter ture, which in this case brought disaster to a fishery.

On the basis of present knowledge, the source of the abnormally cold responsible for such a flooding is to be found to the eastward. A study of the water off the Scotian Shelf (MCLELLAN, *et al.*, 1953), has shown that, betwe northern boundary of the slope water and the continental slope, there is fou varying quantities a body of cold water, less than 0·0° C off the Grand Bank less than 4·0° C east of Sable Island. The quantity of such water, acting as a cu between the slope water and the continental slope, decreases with westward progr until the slope water generally makes contact with the continental slope to the ward of Emerald Bank. Northerly and southerly migrations of the northern e the slope water regime, and westerly progressions and easterly withdrawals colder waters along the continental slope, provide the mechanism for pro sharp and sudden changes in the water temperatures on the continental slope an the outer areas of the continental shelf. While the disaster to the tilefish was of import, and the westerly progression of cold water must have been greater than n similar phenomena on a less spectacular scale have been noted in recent years.

THE EXPANSION OF A FISHERY

In contrast, both as to time and extent, to the temporary incursion of colder w bringing about the destruction of a fishery over a limited area, is the historical of the expansion of the Greenland fishery in recent years with the strengthening Atlantic influence in northern latitudes.

Passing over earlier history, about 1820, cod were known to be present in eno quantities in West Greenland waters, as far north as Disko Bay (JENSEN and HA 1931). Thereafter, they were absent for a long period of years. Between 1845 and cod were again plentiful in the Greenland area and then entirely disappeared. 1917 there was a marked upward tendency in the fishery. The catch increased approximately 1,000 tons in 1925 to greater than 12,000 tons by 1945, and this has persisted to the present. In dealing with the state of the West Greenland C up to 1944, DUNBAR (1946) points out that, by 1928, the waters for the west co Greenland were considerably warmer than in the preceding period, and that th warm year was reached within the period 1930-40. The increasing Atlantic inf however was clearly evident in Latitude 72° N in 1942. A comparison of oc graphic conditions in Hudson Bay and Hudson Strait, as observed in 1930, with of 1948 (BAILEY and HACHEY, 1951) has shown that the observed higher temper and salinities of 1948 are indicative of the increasing Atlantic influence in no waters generally. A meteorological study of Sherbog (DUNBAR, 1946), has sug that the warming of the Arctic and sub-Arctic regions from Greenland to S which has taken place in recent years, is one manifestation of a large scale cl

f a period of about 225 years, which has presumably passed its maximum. It e stressed here that the expansion of the Greenland cod fishery is associated e extension of warmer Atlantic waters into more northerly latitudes, although extension is probably associated with the climatic cycle.

THE LOSS OF LARVAE

ies on the replacement of Bay of Fundy waters were initiated some years ago EY, 1934), and it became evident that the main factors involved in the replace- of these waters were land drainage, wind, and tide. Other things being equal, ess of south-westerly winds favoured the retention of surface waters within the d thus nullified the normal dynamic tendency for surface outflow and renewal waters at greater depths. Under such conditions a type of " closed circulation " ip within the Bay, as opposed to an " open circulation " when surface waters rried out of the Bay to be replaced by inflowing deeper waters. During the r months the " closed circulation " favours higher surface water temperatures, e surface temperatures, as well as the temperature gradient in the upper layer, used as an indication of the type of circulation prevailing. DICKIE (1955) has use of the temperature data for the Bay of Fundy to show that successful year of scallop are produced in those years when the " closed circulation " prevails. nly do the warmer surface waters hasten development of the scallop larvae to tting stage, but the " closed circulation " favours the retention of the larvae the Bay where they settle and grow on suitable scallop bottom. Under the circulation " system, as indicated by lowered surface temperatures, the larvae rried out of the Bay and are lost to the Bay of Fundy scallop fishery.

replacement of Bay of Fundy waters is not necessarily a regular progressive s, even when the " open circulation " system prevails. KETCHUM and KEEN have worked out various mean flushing times and exchange ratios for various of the Bay of Fundy, and they point out that although their conclusions were upon the distribution of river water, the same exchanges may be expected for aterial or organism transported by the water. KETCHUM and KEEN calculated erage flushing time of 74 days for that part of the Bay of Fundy between Cape ecto and a line south of Grand Manan. BAILEY (1953) has shown that within eriod October 6th, 1952, and November 21st, 1952, the waters of the Bay of y were almost completely replaced, a replacement that only became apparent it was found that the salinity throughout a section had increased by more than within the period. It might be emphasized that within this period of forty- ys (or less), practically all free-moving larvae in the surface layers would been carried out of the Bay of Fundy. So too would all free-swimming forms were feeding at random. The higher salinities as found on November 21st te that the replacement involved the inward movement of waters originating sub-surface depths, and these waters would necessarily carry into the Bay wimming forms, and free swimming forms which were feeding at random.

cording to WALFORD (1938) the survival of the eggs and larvae of the haddock eorges Bank is dependent on the variations in the current system in this area, variations being controlled to a large extent by winds (BIGELOW, 1927, 857). ggests that the loss of the eggs and larval population in 1932, which occurred time after the first week of March, was due to the removal by currents. Similarly

Bigelow (1926, 77) wrote: " at the time of our March and April visits (to the n eastern part of Georges Bank) in 1920, the presence of newly spawned eggs in ab ance right out to the 1,000 metre contour proved that a drift out to sea was then t place from the southern point of the Bank." Walford (1938, 49) states: " ther a very important difference between the circulatory picture in the season of and that of the corresponding period in 1931. While in 1931 the water move were such as to permit the bulk of the eggs to remain on the bank and hatch in 1932 there were currents carrying eggs off the northern and southern edge deep water where they were probably lost to Georges Bank." In summary, Wal (1938, 55) points out that a change in the circulatory system on Georges Bank be disastrous to the haddock brood, and consequently, may be an important ca fluctuations in abundance.

Carruthers, *et al.* (1951) have directed attention to the variations in brood str in the North Sea haddock in the light of relevant wind conditions, and the resu these studies have directed considerable effort to the analysis of wind syste related to other North Sea Fisheries.

AVAILABILITY OF THE FISH

The displacement of surface waters on a grand scale by wind is amply demonst by the great ocean currents of the North Atlantic, and the fundamental prin have been thoroughly outlined in the classical work of Ekman (Sverdrup, 1942, 492). Ekman has shown on a theoretical basis that a surface current set wind is directed 45° to the right of the wind direction in the northern hemisp and this has been shown by observation to be a satisfactory approximation in water. In shallow water the deflection of the surface wind current is smaller. A blowing parallel to a coast is thus effective in transporting surface waters towar coast, when the coast is to the right of the wind (*cum sole* from the wind directi the northern hemisphere, and away from the coast when the coast is to the left wind.

The capture of young herring along the open coasts of the Bay of Fundy an Gulf of Maine is chiefly dependent upon fixed shore weirs. Huntsman (1934) s " that the herring are to a considerable extent quite near the surface durin twenty-four hours of the day is not only a matter of direct observation, but a req for successful operation of the weirs." Huntsman also states (1934, 96) that herring may be treated as a planktonic form ". It then becomes evident that h in the surface waters, and considered as a planktonic form, will be moved on or o shore with the varying direction of the wind. This is particularly pertinent open coast, such as that of Maine, and the south coast of New Brunswick, whe availability of the herring to the shore-fixed weirs must be determined in part b varying strength of the prevailing south-west winds during the summer months

TEMPORARY ADJUSTMENTS IN A FISHERY

Large scale water replacements of a temporary nature sometimes bring sharp and sudden changes in water temperature, the changes in environment sufficient to cause a body of fish to either:

(a) move away from a fishing ground, or
(b) cease feeding and thus fail to be attracted to the bait.

water replacements in the Halifax area associated with the formation and uent movement of a tropical cyclone have been described (HACHEY, 1934), has been shown that bottom water temperatures in some of the inshore areas sed from 2·0° C to greater than 15·0° C in less than one week. Under these istances, in these areas, all fishing for cod and haddock ceases, and does not e until temperatures return to more normal values (HACHEY, 1934; MCKENZIE, VLADYKOV, 1933).

rsions of warmer slope water over the Scotian Shelf have been observed EY, 1953), when bottom temperatures reached values as high as 12·0° C, five degrees above normal seasonal temperatures. While no records of fishing are available for periods in which such incursions have been observed, it is well that such bottom water temperatures are unfavourable to cod and haddock, undfish probably moving out of the areas subjected to the incursions of waters h temperatures.

BARREN SEA FLOOR

he Gulf of St. Lawrence comparatively extreme variations in temperature and y have been observed at depth during the summer months (LAUZIER, 1952) ht about by oscillations of the various water layers of contrasting characteristics radually shoaling sea floor. It has been pointed out by LAUZIER that organisms cannot tolerate these sudden changes in temperature and salinity will not form tant populations along the margins of the Magdalen Shallows, and HUNTSMAN has shown that there are bands of the sea floor between Cape Breton and the alen Shallows which are comparatively barren. The oscillation of these water of contrasting temperatures is probably responsible for the periodic complete ction of scallop beds which become temporarily established and fishable under nally satisfactory conditions in the Magdalen Shallows (Annual Report for Fisheries Research Board of Canada, 34).

MARGINAL FISHERIES

Canadian Atlantic waters, which are contained in the area of confluence of three t systems with waters of contrasting characteristics, extreme contrasts in water teristics, chiefly temperature, are to be observed. Very sharp boundaries, both lly and horizontally, are thus encountered, and various marine organisms le to one environment (frigid) or another (temperate) exist on a marginal basis. ll vertical or horizontal change in the margin sometimes exerts a very pronounced on a fishery.

h progressive warming of the waters during recent years we have witnessed rtherly expansion of successful oyster production in the Gulf of St. Lawrence, e northerly extension of the green crab to the Bay of Fundy (Annual Report 53, Fisheries Research Board of Canada, 25). As mentioned earlier in this the expansion of the west Greenland cod fishery is probably the most outstand- ult of the increased Atlantic influence in northern waters. It is to be expected downward trend of temperatures would bring about a recession of these ons.

me cases, man is responsible for changes in environmental conditions, and this icularly true in estuaries where pollution problems arise with present-day

industrial developments. Of a different nature are the possible changes in environment of Georges Bay, between Cape Breton and the Nova Scotia mainla which may follow from the completion of the Canso Causeway. By cutting off interchange between Gulf waters and those of the open Atlantic through Ca Strait, the strong possibility exists that the waters of Georges Bay will be warmer t heretofore. Slight upward changes in the water temperatures in this area may sufficient to exert some influence on the lobster populations, and to bring abou southward extension of the oyster populations of neighbouring areas.

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STUDIES ON CANADIAN ATLANTIC SALMON

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Atlantic salmon have been an important natural resource of eastern Canada from earliest times. For over 100 years, fluctuations in the yearly harvest have given rise to concern about the survival of the fishery. Commercial landings and values in the last two years are given in Table 1.

In addition to the commercial fishery there is an important sport fishery for salmon. The dollar value of this, while difficult to assess with any accuracy, probably equals or even exceeds the value of the commercial fishery.

Widespread concern about the future of our salmon led to the formation, in 1949, of a Federal-Provincial Co-ordinating Committee

TABLE 1. RECENT VALUES OF COMMERCIAL ATLANTIC SALMON FISHERIES IN CANADA.

	1953		1954	
Province	Pounds	Dollars	Pounds	Dollars
Newfoundland	3,088,000	705,000	2,153,000	519,000
New Brunswick	650,000	266,000	853,000	368,000
Nova Scotia	269,000	117,000	226,000	103,000
Quebec	526,000	203,000	444,000	197,000
Total	4,533,000	1,291,000	3,676,000	1,187,000

on Atlantic Salmon. Upon recommendation of this committee, increased emphasis was placed on the importance of salmon. The Fisheries Research Board of Canada expanded its research program, with the Province of Quebec participating in one phase. In addition, the Department of Fisheries expanded its salmon management program.

FLUCTUATIONS IN CATCH

Systematic records of mainland commercial catches are available since 1870. These show wide fluctuations in the annual landings, with a rather steady decline during the last 25 years. This decline has given rise to opinions that salmon stocks are being damaged by overfishing.

Too heavy removal of a year-class would result in a relative scarcity of its progeny. In the Gulf Area of the Maritime Region there is a period of six years between related generations, for nearly all the salmon. This area extends from Cape Gaspé, Quebec, to Cape Breton, Nova Scotia, and accounts for about two-thirds of the commercial landings for the mainland. The annual landings in this Gulf Area for the past 85 years are shown in Figure 1, A. The downward trend of the last 25 years shows clearly. It started at a time when catches were at an exceptionally high level. But the lowest recent year (1953) was not quite as low as the lowest year of the record (1881). The landings for the first 79 years of this period are arranged in order of magnitude, with catches of similar magnitude in chronological order from left to right, (Figure 1, B, upper part). These are the amounts removed from "parent" year-classes. Immediately below each of these "parent" catches are the catches six years later (lower part of Figure 1, B), which are the amounts removed from corresponding "progeny," or "offspring," year-classes.

While the parent catches have been given a definite order in respect to size, their corresponding progeny catches show only a random distribution. This is evidence that large removals from parent stocks have not had any effect on catches in subsequent years. It seems doubtful, therefore, whether additional restrictions on catches would lead to better fishing. However, other ways of increasing the value of our salmon are being brought to light.

PROGRESS IN RESEARCH

In Canada, there has been fairly intensive and continuous investigation of Atlantic salmon problems since 1930. This laid a foundation of knowledge about the life history of salmon and provided experience in useful research techniques. Figure 2 illustrates the general features

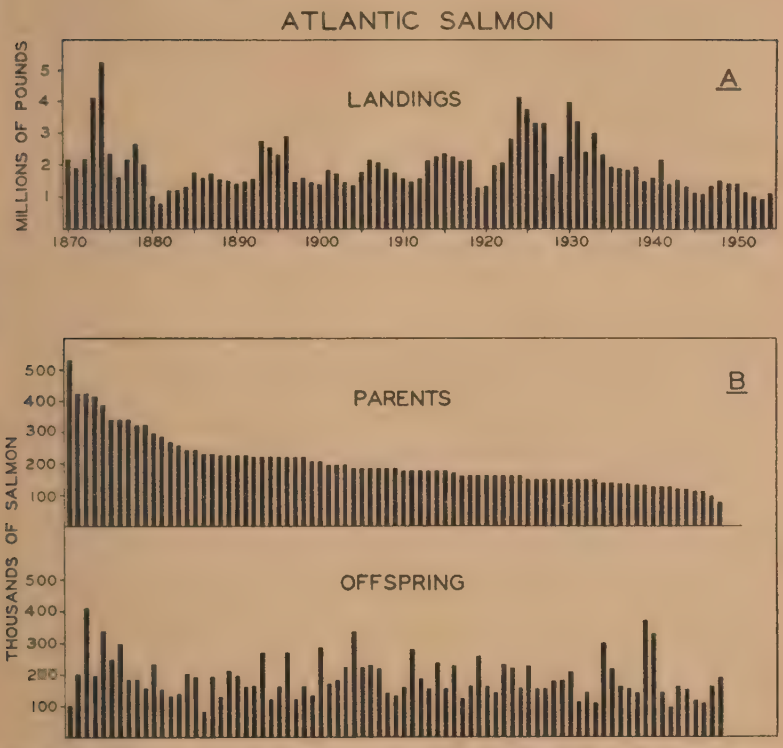

Figure 1. Commercial landings of Atlantic salmon from the Gulf Area (Cape Gaspé to Cape Breton) of the Maritime Region for the past 85 years.
A. Annual landings in chronological order.
B. Same catches plotted as numbers of 10-lb. salmon. Upper panel: numbers of parents in the first 79 years arranged in order of magnitude. Lower panel: numbers of offspring caught 6 years later, drawn directly below corresponding parent catch.

of the life cycle of Atlantic salmon. The duration of river and sea life varies more than indicated. The relationships of the different stages to fisheries are shown. Some of the interesting developments are outlined under the six topics below.

1. *Utilization of salmon stocks.*—Salmon taken in the various commercial fishing areas of the sea, including the estuaries of large rivers, may be produced by many fresh-water streams, often far away. For example, salmon marked as smolts in New Brunswick streams (Miramichi and Pollett Rivers) have been taken in relatively large numbers around Newfoundland, particularly along its east coast. Of those marked in the Miramichi, many have been taken as adult salmon in

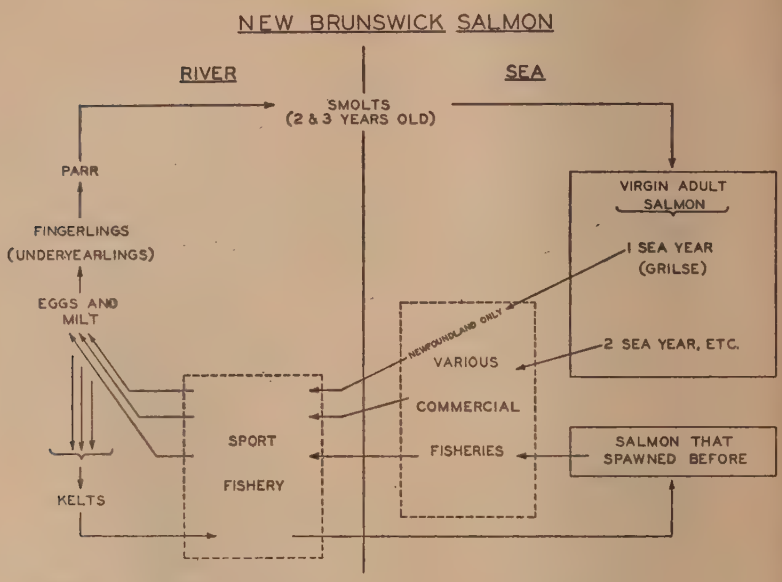

Figure 2. Life cycle and utilization of Atlantic salmon in New Brunswick, Canada.

the nearby drift-net fishery and in trap-nets extending up to head-of-tide. Many Pollett salmon which must have traveled several hundred miles were taken here also. In fresh water, however, marked adults have been recaptured only in the river system from which they came.

These points are shown in Figure 3 which illustrates the data of Table 2.

Since 1952, the smolt-marking program has been expanded. Marking traps are now operated on the Port Daniel River, Quebec, and the Little Codroy River, Newfoundland.

2. *The Miramichi salmon fishery.*—The Miramichi system is the center of the largest Atlantic salmon fishery in Canada. In this area studies are being made of the times, and sizes of runs of grilse and older salmon, in the various commercial and sport fisheries. These are combined with an analysis of life cycles based on scale reading. Such information is needed to evaluate the merits of present and proposed fishery regulations.

About the middle of May, a run of large salmon enters fresh water, followed in mid-June by a larger run of grilse. Both are eagerly sought by sportsmen after the angling season opens on June 5. Large

TABLE 2. RECAPTURES BY OCTOBER, 1953, OF ATLANTIC SALMON MARKED AS SMOLTS IN 1951.

Recaptures to October 1,1953 by	Marked as decending smolts in 1951				
	Northwest Miramichi River 33,407	Dungarvon River 14,966	Total Miramichi River 48,373	Pollett River 25,187	Total 73,560
Drift nets (sea)					
Miramichi area	100	83	183	17	200
Shore nets (sea)					
Newfoundland	117	84	201	79	280
Bay Chaleur	4	4	8	....	8
Miramchi area	198	57	255	12	267
Nova Scotia (outer coast)	2	....	2	19	21
Bay of Fundy	....	....	....	5	5
Anglers (fresh water)					
Miramichi black salmon	42	19	61	....	61
Miramichi bright salmon	143	43	186	....	186
Total	606	290	896	132	1,028

salmon in the sea can be taken by a limited number of commercial fishermen using offshore drift-nets and estuarial trap nets; these commercial fisheries also open on June 5. This opening date for all fishing came into effect in 1954 on the recommendation of the Co-ordinating Committee on Atlantic Salmon. It is later than formerly, to allow more of the early-run stock to reach the spawning grounds.

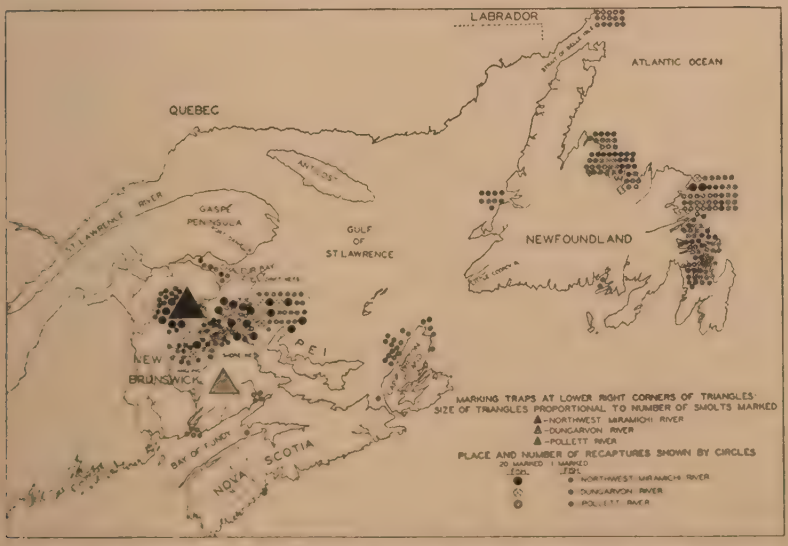

Figure 3. Recaptures by October 1953 of Atlantic salmon marked as smolts in 1951.

Throughout the Maritime region corresponding changes were made in the opening dates. In the Miramichi area both commercial and angling catches in 1954 were much higher than in the two preceding years. Since conditions for both angling and commercial fishing were not the best, owing to continuous high water and bad weather, it is believed that an abundant spawning stock was available in 1954.

In mid-summer the runs of both grilse and older salmon shrink to a very low level even when high water prevails, as in 1954. The fall run starts in September, ends in early November, and comprises fewer grilse but more big salmon than the early run. All commercial fishing is over by August 31, and in most branches the angling season closes on September 30.

One controversial topic has been "black salmon" angling for kelts which is permitted here from ice break-up to May 24. This sport is permitted because there is evidence that fewer than 10 per cent of kelts subsequently reappear in fisheries. A recent tagging experiment has shown that a large portion of this catch consists of late-run salmon that entered fresh water the previous autumn. Relatively few of the more valued early-run stock are taken by black salmon anglers (Table 3).

The black salmon fishery appears to be a worthwhile use for the late-run stock which is quite plentiful in the Miramichi area. Black salmon account for about one-quarter of the total Miramichi angling catch.

In 1954 the total commercial catch in the Miramichi area was just under 49,000 salmon, based on a 10-pound average weight. The

TABLE 3. RECOVERIES BY BLACK SALMON ANGLERS IN 1953, OF ATLANTIC SALMON TAGGED IN MIRAMICHI AREA IN 1952..

	Month of Tagging						
	June	July Mostly Early-run	Aug.	Sept.	Oct. All True Late-run	Nov.	Total
Total tags applied:	230	268	58	842	659	105	2,162
Tags remaining by winter 1952-53, after 1952 fishing season:	198	236	53	826	658	105	2,076
Recovered by black salmon anglers, 1953:							
April	7	6	2	92	97	16	220
May	1	3		22	40	7	73
June				2	4	1	7
July	1			1			2
Total	9	9	2	117	141	24	302
Percentage of available tags (monthly groups) taken by black salmon anglers:	5%	4%	4%	14%	22%	23%	

angling catch, including black salmon, totalled almost 34,000 fish. Official records of the angling catch show that of the fresh-run fish taken, more than half are grilse.

3. *Fish-eating birds.*—Natural history studies have shown that some fish-eating birds prey heavily on young salmon. Mergansers, especially *Mergus merganser,* and kingfishers, *Megaceryle alcyon,* are the important species. Intensive studies of these birds on salmon waters have shown that mergansers do by far the most damage. These fish-ducks are relatively abundant on many salmon streams. The quantitative effects of bird control were studied on a 10-mile section of the Pollett river. When there were 30 to 40 mergansers reared annually and twice as many seasonal invaders, smolt production from 16,000 planted fingerlings did not exceed 2,000 per year. Even when 15 times as many fingerlings were planted, annual production was scarcely doubled. The mean production from three plantings of 16,000, one of 48,000 and one of 249,000 fingerlings was 2,400 smolts per year. But when mergansers (and kingfishers) were controlled by semi-weekly patrols, average production from 4 plantings of about 250,000 fingerlings each, jumped to 19,000 smolts, *i.e.* by 8 times.

Systematic control of mergansers was then applied to the Northwest Miramichi, a well-known angling stream where the stock is supplied by natural spawning. Annual sampling of young salmon populations was carried out on this stream and the similar Dungarvon River. The latter is also a tributary of the Miramichi system, but one where there was no organized control of mergansers. Average population densities found in 1952 and 1953 combined, are illustrated in Figure 4, A. Both streams had similar runs of adult salmon, and similar populations of young salmon less than one year old. But two years after starting control on the Northwest, the large parr, which would become smolts nine moths after the sampling, had increased by more than four times. At this time the Dungarvon had only half as many large parr as the Northwest. The Dungarvon parr were subject to attack by mergansers for another nine months before migrating as smolts.

Experimental merganser control has been extended to cover the entire Miramichi system in New Brunswick and the St. Mary River in Nova Scotia, so that its effect on associated sport and commercial fisheries can be evaluated.

4. *Experiments with hatchery stock.*—The amount of hatchery stock which must be planted to get the best yield of smolts was studied on the Pollett River, after establishing bird control as a necessary

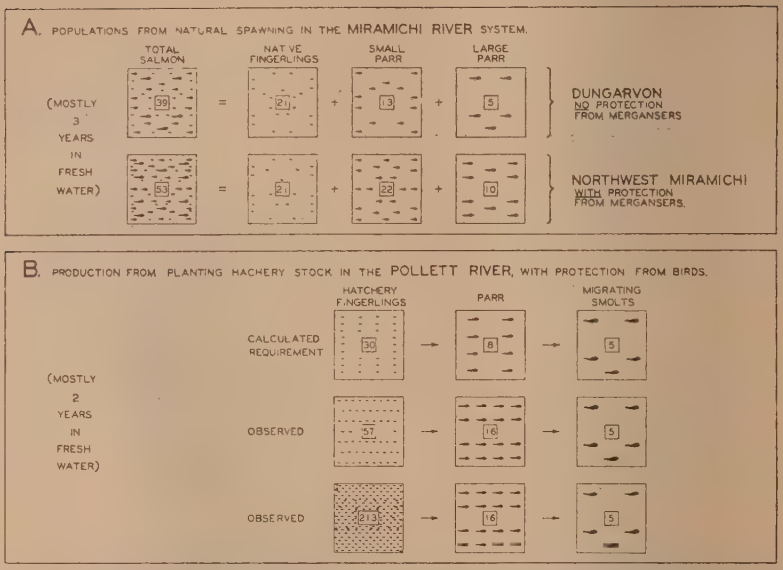

Figure 4. Average numbers of young salmon per 100 sq. yd. of stream bottom, in New Brunswick. With protection from mergansers the number of large parr in the Miramichi compared favourably with the calculated requirement for the Pollett.

adjunct of good production. Heavy populations of hatchery fingerlings were planted in order to learn the capacity of the experimental area to produce migrating smolts. Very light populations were used to determine best survival rates. The amount of hatchery stock required to get full yields of smolts has been calculated from the resulting figures. During the course of this work the parr were sampled systematically each year, using seining and electrofishing techniques. Thus it has been possible to determine figures not only for numbers of hatchery fingerlings, but also for numbers of larger parr required to give best smolt yields. These experiments involved hundreds of thousands of fingerlings and tens of thousands of parr and of smolts. Results have been reduced to numbers per 100 square yards of stream bottom (Figure 4, B). It now appears that the maximum smolt yield to be expected from the Pollett should be obtained by planting hatchery fingerlings at a rate of 30 per 100 square yards to give 8 yearling parr and 5 smolts per 100 square yards. While up to 16 parr have been obtained from heavier plantings these have still given only 5 smolts; this seems to be the maximum rate of smolt production.

Standardized measurements of population densities make compari-

sons between numbers in different streams relatively simple (see Figure 4, A and B). This is a step towards determining whether streams are supporting as many young salmon as they should.

5. *Number of adults to maintain stocks.*—How many spawners must rivers have to keep stocks at highest levels? This question must be answered if we are to take full advantage of our salmon resources. Measurements have been started on survival rates between various stages from eggs brought into rivers by mature fish, through fingerlings and parr to smolts leaving. Preliminary information from both the Pollett and the Miramichi suggests that relatively high smolt production can be obtained (using merganser control) if eggs are brought in at an approximate rate of 300 per 100 square yards of stream bottom. For a small to medium river (30 to 70 miles of salmon-rearing water) this requirement is roughly equivalent to 150 pounds of female salmon per mile of stream, whether they be 3-pound grilse or 10-pound older fish. Both the Northwest Miramichi and the Dungarvon receive females at a slightly lower rate and both appear to have good numbers of underyearlings (Figure 4, B). The poundage given for adult females allows for usual removal by angling and so on.

6. *Effects of DDT on salmon.*—In early June, 1954, about 1 million acres of budworm-infested woodland in New Brunswick were sprayed from aircraft, using one-half pound of DDT per acre. The area sprayed included most of the Northwest Miramichi and the upper reaches of the Dungarvon Rivers. Because studies of salmon in these streams have included yearly quantitative samplings of young, it is possible to gauge the effects of the spraying on salmon production.

Young salmon were held in cages in the streams during the spraying operations. About 80 per cent of those held within the sprayed area died within a week. Ten miles below the area of direct application only 16 per cent died within four weeks, and 15 miles below only 4 per cent. Dead and dying parr were observed throughout the sprayed area, and even to 15 miles below it, as long as four months after spraying. No such mortality had been observed in earlier years. Thus there were delayed effects in addition to the killing immediately after the DDT was spread.

The annual samplings were made in late August as usual, nearly three months after the DDT was applied. *No* fingerlings (fish of the year) were found in the sprayed sections and they were very scarce for at least 10 miles below these areas. Small parr (mostly yearlings) and large parr (mostly two-year olds) were reduced to *one-*

sixth and *two-thirds* respectively, of their levels of abundance in the two preceding years. Adult salmon entering the river during the summer did not appear to have been affected at all.

Aquatic stages of insects such as mayflies, stone-flies, caddis-flies and midges, which form the food of young salmon, were extensively killed. The possibility of replenishing these insects from outside sources is under consideration. Unless remedies can be found, it may take some years to reach former levels of production.

DISCUSSION

DISCUSSION LEADER SARGENT: Dr. Elson, in my State of Massachusetts, we have practically no salmon fishery. You mentioned, I believe, that the salmon was about fortieth of the commercial catch. In Massachusetts our total catch is forty salmon if it is a particularly good year. What I wondered about is how you obtain your sport catch statistics, whether they are accurate, and whether they are included in your total figures. I would assume that that is quite an important part.

DR. ELSON: Fortieth is the value. It's the sixth most important fish. But these values I gave you of a little over a million dollars a year do not include the sport fishery at all. It is just the commercial value. Sport fishery is worth just as much if not more, so we'll put a two million dollar tag on. I have the feeling myself that the one million dollar figure for sport fishery is probably a little on the low side. I am sure that any enthusiastic salmon angler would agree with me. In fact, he would say I was very pessimistic in setting the value so low, but the value given in the paper is the commercial fishery value.

DISCUSSION LEADER SARGENT: Do you have any method of ascertaining the total catch by sport fishermen?

DR. ELSON: Yes. Our fishery wardens attempt to get records from anglers as they travel the streams. We have contact with most of the salmon camps in the Miramichi area, for example, and get our records there. The department does get records from its inspectors of the salmon that are caught by sport means on the various rivers throughout all the Maritime Provinces.

MR. BRUCE LANE [New Brunswick]: I would like to ask Dr. Elson a question. It seems to me we are debating the issue here. We have a problem which Dr. Elson tells us is doing more damage than anything else to the fishery resource which is the spraying with wide-scale DDT, and we hear a lot about the damage the mergansers do, and as an afterthought, at the tail end of the paper, Dr. Elson made some few remarks of the devastating effect of this broad-scale spraying.

I would like him to elaborate a bit more on what he considers the over-all effect on New Brunswick salmon after five or six years of this continuous spraying of the headwaters of our waters.

DR. ELSON: I should say that the people who kill salmon are fairly close to the people who are trying to look after the interest of the salmon. We had a meeting with them early in February, and a very pleasant cooperative spirit was expressed on their part, and we were glad to see it.

Actually, this year at least, while there will be a little bit of spraying again, we have been shown their maps, as we were shown last year—and I expect we shall be shown in the future—and there will not be any spraying of waters this year which proves very vital to salmon protection. I think if one has to balance salmon against forestry for New Brunswick, or for any of our Maritime Provinces. I have a feeling that perhaps I would be on a losing side of the game. In other words, the forestry, at the present time anyway, is worth a lot of money.

The forestry people are spraying rather small amounts. They do not expect to spray the same area year after year. They expressed the opinion this year that it might be necessary to spray every third year in the same area, but they felt

quite confident that it would not be necessary to spray more often than that. We still don't know.

The insects were very, very drastically reduced, and they were in some cases almost eliminated. Some of them were types which do not replace very rapidly; that is, they don't fly very great distances, and if they are eliminated from the headwaters down, perhaps three years won't be enough to get good populations of insects so that the salmon will have good eating again.

This year we are going to concentrate on that particular aspect of it. Of course, there is always the hope that the chemists may come up with some compound that won't be quite so bad. I believe the DDT disintegrates very rapidly in an alkaline area. Unfortunately, most of our salmon streams seem to have a low pH. Of course the ground has a low pH because the water reflects the ground. I think that perhaps if we had some other poison than DDT, the effects would be less drastic.

All I can say at the present time is that the forest people are in touch with the salmon people and are trying to plan their program with a minimum of harm to the salmon, and they have expressed a willingness to cooperate in any experiments. They have even suggested that they might attempt to set up some experiments to look further into this matter of forests versus salmon.

DISCUSSION LEADER SARGENT: Dr. Elson, referring to our state again, we do DDT spraying for gypsy moss. Before the program starts, they plot out very carefully all of the waters and streams and prevent the planes from flying over that path. I was wondering if this could not be done. It seems to me that with control you would be able to eliminate most of the DDT getting into the water. However, I realize that with a wind you would occasionally get a drifting of the spray, but I should think it would be possible to control some of that.

DR. ELSON: As a matter of fact, our air pilots like to fly but they don't like to get lost. They use streams as boundaries for their various courses. This often results in a stream being covered twice. However, I think perhaps this was expressed by the manager of Forest Protection when we were discussing the whole business. He said, "You know, we don't know where half of the DDT goes. We have put out spray cards which are supposed to pick up the droplets. They are scattered all through the area." They try to assess the distribution of the DDT, but they don't know where at least half of it goes.

I think this means that no matter what courses they flew, because of wind drifts and unkown factors, the course they flew would not make very much difference. If they are going to spray the forest areas which includes the salmon streams, they are going to get some DDT in the salmon streams. Perhaps some of it will only flow as you get rains washing it down from the soil later, but it is going to get there.

I would like to add one more thing. I know you have an Atlantic Salmon Fishery down in Massachusetts. A few years ago we had some salmon tagged in Nova Scotia, and about six months later one of them was returned from Massachusetts.

DISCUSSION LEADER SARGENT: I think I know the fish.

MR. HARRY W. WALTERS [St. Johns, Newfoundland]: I would like to ask Dr. Elson in making reference to standards of 150 pounds providing sufficient parr for a river, I wonder if he includes the whole watershed or just those areas suitable for propagation.

DR. ELSON: That 150 pounds are adult female salmon per mile, and that is just sort of a ready figure for somebody to think of. This is just a sort of popular consumption ready figure which will form the basis of a calculation for all salmon. The average would be 150 pounds per mile. Obviously a narrow part is not going to take anything like that. As you get down to the lower end of a 70 mile stream, it is going to be quite wide and could stand a little bit more than that, but this figure is actually based on ten miles of a stream which ran at summer level about 75 feet wide.

MR. PIMLOTT [St. Johns, Newfoundland]: I appreciate Dr. Elson's remarks,

but we hear many rumors coming out of New Brunswick that this control is by no means effective. If that is the case, the comparative levels of the two values may be much higher than it would be here. I wondered, too, about the effect of extensive pulp wood-cutting operations on watersheds such as one finds in Newfoundland. I wondered if the Fisheries Research Board is doing any work on the effect of large-scale pulp and paper operations on streams in Newfoundland.

Dr. Elson: So far as I know, there has been nothing like that going ahead.

I would be very glad to talk salmon with anybody who is interested, after the meeting, or any time during the day.

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UTILIZATION OF ATLANTIC HARP SEAL POPULATIONS

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The purpose of this paper is to summarize some of the results of recent research on harp seals (*Phoca groenlandica*) in the west Atlantic, and to indicate desirable steps for management of the resource in the light of present economic utilization.

Distribution and Movements

The harp seal ranges from the Canadian eastern Arctic and east coast eastward to Novaya Zemlya and adjacent Soviet areas. There are three major populations which can be referred to as the Eastern, breeding in the White Sea; the Central, breeding in the Jan Mayen Island area; and the Western, breeding off the east coast of Canada (Fig. 1). The Western groups breed in two localities: the Gulf of St. Lawrence and the east coast of Newfoundland. The species is strongly migratory and occupies the southern area of pack ice for spring breeding, moving northward to occupy high Arctic areas of open water during the summer and early autumn.

The recent warming trend in Arctic waters has materially affected the distribution and movements of the harp seal, at least for the Western group. Summer distribution to the east of the Canadian Arctic for example 30 or 40 years ago was concentrated around the southwest portion of Greenland. With the extension of open water areas to the north, and of many species of food animals of the harp seal, it now ranges in summer north to Thule. This has largely contributed to a change-over in the economy of the people of southern

Figure 1. Polar projection showing the approximate range and breeding sites of the three major populations of the harp seal.

Greenland from one based on seal hunting to one based on sheep-farming (Dunbar, 1947). While this northward extension in range has changed the time of arrival of southward migrants at Belle Isle from November to January, it does not appear to have materially affected the timing of the whelping season.

The distribution and times of whelping and mating of the three major groups are compared in Table 1.

The northward movement in all groups begins with the formation of the moulting patches in the pack ice. These are composed at first almost entirely of adult males, which haul out in herds of various size immediately following the mating season. They are gradually joined by the immatures of both sexes and by the adult females, with

TABLE 1. COMPARISON OF WHELPING, MATING AND RANGE IN THE THREE MAJOR BREEDING GROUPS OF THE HARP SEAL.

	Whelping	Mating	Northern range
Western:	Late February-mid March	Mid March-early April	West coast Greenland to Thule; east coast Baffin Island to Devon Island; north Hudson Bay.
Central:	Late March into April	Mid April-early May	West coast Spitzbergen; east coast Greenland.
Eastern:	Mid February-early March	Last three weeks March	Northwest coast Novaya Zemlya; east coast Spitzbergen.

a sudden influx of the latter towards the end of April. The pack drifts south, so to make northward progress the animals periodically enter the water and move north for short distances before reappearing on the pack again. By the end of May, at the latest, all seals from the east coast of Newfoundland are north of Belle Isle.

Suitable ice does not persist long enough in the Gulf of St. Lawrence for complete moulting on ice. There is some evidence that the seals in this area complete the moult in the water, although the possiblity that some of them leave the Gulf to join the moulting groups east of Newfoundland and Labrador has not been eliminated.

EXTENT OF KILL

For over 200 years there has been commercial hunting of harp seals in the northwest Atlantic. It is not possible here to go into detail on its interesting history, which is given quite fully by Chafe (1923) and which is reviewed more recently by Colman (1937, 1949).

The white-coated pup is the chief target of the industry. Before World War II, almost 90 per cent of the catch was of pups. Now many older seals are taken as well, constituting up to 40 per cent of the take. The greatest annual kills took place between 1820 and 1860, when over half a million seals were taken in some years. The largest kill on record is that of 1831, when 687,000 seals were taken by some 300 ships and 10,000 men. Steam vessels had replaced sailing schooners by 1871, largely through the influence of Scottish sealers and whalers from Peterhead and Dundee, who operated in the northwest Atlantic between 1790 and 1910. For the next 40 years from 250,000 to 300,000 seals were taken annually. World War I reduced this kill by half.

World War II took most of the sealing ships out of action. There was relatively very little sealing from 1941 to 1946, none in 1943.

Since the end of the war a Canadian fleet of some 10 or 12 motor vessels has been developed for sealing. Many of these are based in Nova Scotia. Some have been built specifically for the job. In addi-

tion a Norwegian fleet of some eight to 11 vessels has joined in the sealing off Newfoundland and in the Gulf of St. Lawrence, largely resulting from Norway's inability to re-obtain from Russia the sealing concessions she formerly held in the White Sea.

The pups are taken on the ice largely in the first half of March. Scattered "beaters" (pups which have moulted the white natal coat and are taking to the water) are taken late in March and in April. Bedlamers (immature harp seals) and adults are shot on the ice while moulting during April and May. Virtually all pelts with adherent blubber, called "sculps," are removed on the ice and dragged or winched to the ship. They are stored in holds with ice. The newer vessels have refrigerated holds.

Of 10,200,000 seals taken between 1895 and 1946, 96 per cent were harp seals. The remainder were hooded seals (*Cystophora cristata*), which at the present time form less than 1 per cent of the catch.

The kill statistics for harps from 1895 on are divided into three

TABLE 2. AVERAGE ANNUAL KILL FOR THREE AGE GROUPS OF HARP SEALS FOR GIVEN PERIODS FROM 1895 TO 1954.

Period	Countries	Ships	Young	Adults and bedlamers	Proportion older seals	Totals
1895-1911	Nfld.	20	228,000	21,000	8%	249,000
1912-1940	Nfld. (Norway 1938-9)	10	134,000	25,000	16%	159,000
1941-1948	Nfld. Norway	9	24,000	22,000	48%	46,000
1949-1954	Canada Norway	22	161,000	68,000	30%	229,000

age groups: "Young" (pups of the year), "bedlamers" (immatures), and "old" (adults). Average annual figures for given periods, with the percentage of older (immature and adult combined) seals, are given in Table 2. These figures represent the kill by vessels on the east coast of Newfoundland. There is in addition an annual shore-based catch of harp seals in West Greenland of about 50,000 and in Labrador, Quebec and Newfoundland of about 15,000, of mixed age groups.

Figures for the kill in the Gulf of St. Lawrence are available from 1949. They are given in Table 3. These include the kill by vessels, by landsmen walking offshore on ice, and by nets taking southward and northward migrants along the North Shore of the Gulf.

ECONOMIC USES

The north Atlantic sealing industry produces three major commodities: oil, fur and leather. The pup is the most valuable source of

TABLE 8. TOTAL KILL OF HARP SEALS IN THE GULF OF ST. LAWRENCE FROM 1949 TO 1953.

Year	Hunting	Young	Immatures and adults	Totals Young	Totals Older	Proportion older seals
1949	Shore	16,000	11,000+			
	Ships	22,000	2,200—	38,000	13,200	26%
1950	Shore	.....	12,500			
	Ships	21,500	1,000?	21,500	13,500	30%
1951	Shore	11,800	15,000			
	Ships	70,200	1,100?	82,000	16,100	16%
1952	Shore	5,000	8,200			
	Ships	51,700	7,100	56,700	15,300	21%
1953	Shore	19,000	14,800			
	Ships	4,000	Nil	23,000	14,800	39%
Average:				46,200	14,600	24%

all three. Values in all of these commodities are unstable, but in general it can be said that the oil represents 50 percent of the industry's total revenue, fur 25 per cent, and leather 25 per cent. It is difficult to indicate a figure for the Canadian sealing industry's worth. The over-all quantitative production varies from year to year, and there are large variations in the production itself, caused by variations in the age groups of animals taken. With such variation from year to year, the total average annual value for the past four years of sealing products produced by the Canadian industry is about $363,000 for fur, and for all products, $1,450,000. The value of Norwegian sealing in Canadian offshore waters brings these figures to $575,000 and $2,300,000 respectively.

The pup is the basis of the fur stock. A few other fur skins are produced from older animals, but their total value is negligible. The value of the fur of a harp seal pup varies according to whether it is a hairfast "white-coat" or a "beater." Neither category is true fur. The white coat of the pup is foetal hair. It is retained for two to three weeks and is fast only for 10 days or less. Yet the pup should be two or three days old before it is taken, as newborn animals have little value. The "beater" coat is the short, spotted hair coat which grows in under the white coat. It is similar to the hair coat of the older age groups, but is thicker and softer. The market values of both types of pelt are subject to wide fluctuations. The hair-fast white-coat was worth about double the hair-fast beater for the first few years after World War II. The market for hair-fast beaters has improved, however, and today the beater pelt has a slight edge in value on the white-coat pelt.

Important factors in determining the value of pelts, for both fur and leather production, are, of course, the skinning technique and the way in which the skins are handled before and after deblubbering.

Very slight damage indeed causes a 25 per cent reduction in value. The sculps are very susceptible to knife damage and to a peculiar spoilage known as "ice-burn" when the carcass is left to lie on the ice before sculping. It is a matter of minutes rather than hours, which accounts largely for the somewhat hurried nature of operations on the ice. The introduction of machinery for deblubbering after the sculps are landed was a great stride forward in increasing the value of the skins. There is also the problem of oxidation. Clean unoxidized pelts are sometimes worth as much as double the price of the oxidized variety. Much has been accomplished by the industry recently in developing anti-oxidation techniques.

With respect to oil production, the Canadian sealing industry has been at a great disadvantage compared to their Norwegian competitors. Since the end of World War II, fats and oils have been in brisk demand in Europe. This market is closed to the Canadian producer who must sell his oil in dollars. The total quantity of oil produced by Canadian sealing interests represents only an insignificant percentage of the world's total production of edible oils, but the Canadian market is very reluctant to absorb even this small quantity.

BIOLOGICAL RESEARCH

a. *Aerial photographic survey.* Intensive investigation on harp seal life-history on this side of the Atlantic began in 1949. Høst (1951) carried out probably the first tagging of northwest Atlantic harp seals. Rasmussen (1952) carried out investigations for the Norwegian government. The major study on eastern populations is that of Sivertsen (1941). It was considered of prime importance to gain some idea of the abundance of the animals. During March, 1950 and 1951, an aerial photographic survey technique over the whelping patches in the Gulf of St. Lawrence and off the northeast coast of Newfoundland was tried out with some success. A chartered DC3 aircraft was equipped with two vertical aerial reconnaissance cameras; an automatically operated 6-inch type and a 20-inch type for telephotos. After locating a whelping patch, its area was determined by flying the length and breadth at several points, at a known speed. Photography was carried out at from 200 feet to 3,000 feet altitude depending on light conditions, nervousness of the seals, and the regularity of their distribution on the ice. A strip was flown diagonally across the patch, with the automatic camera photographing every few seconds. The area of each exposure is known, and the total area of the exposures was determined. The adults and pups were counted (the latter from telephoto shots at altitudes of over 600 feet) and the

density per square mile was calculated. From this and the total area of the patch (usually about 50 square miles east of Newfoundland) the total population of pups could be estimated directly. The pups stayed on the ice but an unknown number of adults were in the water under the pack. The proportion of visible adults to pups, however, serves as an index to the stage of whelping. Immatures are not present at all in the whelping patches. Adult males are nearby and begin to enter the whelping patches at least by mid-March.

Estimates of the total population (*i.e.* of adult and immature males and females) were made from the pup census. Photographic coverage was virtually complete in the Gulf of St. Lawrence. The pup production here was estimated to be 215,000. Photographic coverage on the east coast of Labrador and Newfoundland was only about 50 per cent, and visual estimates were combined with photography. The pup production was estimated to be 430,000. The total annual pup production of northwest Atlantic harp seals therefore is estimated to be about 645,000 These were produced by 645,000 adult females (twinning is rare enough to be disregarded). Reproductive success is about 80 per cent as suggested by net catches of southward migrant adult females (Fisher, 1952). The total number of adult females represented by the whelping patches therefore is 805,750. Since the sex ratio is about equal and there is no evidence of a particularly disproportionate kill of sexes, the estimated total number of adult seals is twice this, or 1,611,500—1,074,000 east of Newfoundland and 537,500 in the Gulf of St. Lawrence. Using age compositions of net catches of southward migrants in the Gulf (Fisher, 1952), and of the kill of adults and immatures from moulting patches on the east coast of Newfoundland, the proportion of adults in the total stock was calculated for the Gulf and the east coast, respectively (Fisher and Sergeant, 1954). This resulted in an estimate of 2,067,000 for the total stock of immatures and adults represented by the breeding population east of Newfoundland, and of 1,200,000 represented by the breeding population in the Gulf. The total stock of northwest Atlantic harp seals thus is estimated to be 3,300,00. The method is open to obvious sources of error, *e.g.* the visual estimates east of Newfoundland, and the fact that the age composition data were several years behind the aerial survey data and the population structure may have changed. Another aerial survey, concentrating entirely on the whelping patches east of Newfoundland, is being carried out at this moment as well as intensive sampling of net catches and of the moulting patches for concurrent age composition data.

b. *Reproductive data.* An accurate method of aging harp seals

(Fisher and Mackenzie, 1954) has greatly facilitated reproductive studies. A study of reproductive tracts of known-age animals has produced data on ages at sexual maturity and length of breeding life (Fisher, 1954). The development of the baculum and of spermatogenesis indicates that breeding maturity in the male does not take place before eight years of age. The males come into breeding condition well ahead of the actual mating season, which begins about March 17 and ends early in April. They go out of breeding condition very quickly after the end of March, which probably is an important factor in controlling the regularity of the whelping season.

A study of the ovaries and corpora lutea has revealed that sexual maturity in the female occurs over a range of ages. First ovulations have been observed in animals from five to nine years of age. The corpus albicans remains visible for up to five years. A study of adult females 10 years of age and under indicates that first ovulation takes place largely between the ages of five and eight, with a peak at six.

The maximum life span is well over 30 years, and the average length of life is over 20. Animals of both sexes in their twenties are sexually active. Very few senile animals have been collected.

Female southward migrants taken in early January do not show follicular development at that season until in the fifth year (though it is evident in younger ages during the mating season or shortly after). Southward migrants of both sexes increase in number by age class until in the fifth year. Apparently the stimulus to migrate to the breeding area is not fully felt until the fifth year, since many immatures, in fewer numbers with each successive year-class, lag behind in the Arctic. In the fifth and succeeding year-classes all seals migrate south.

Implantation is delayed in the harp seal for an unknown length of time but probably for about 11 weeks. The phenomenon in this particular case allows mating to occur at the only time of year when the adults are concentrated, and at a time when normal development would produce pups at an unfavorable time of year.

c. *Weight increase and fur fastness in pups.* A peak in weight of pups is reached 16 to 18 days after birth. During this time their weight increases from about 12 pounds at birth up to a maximum of 100 pounds at weaning time. Almost all of this is blubber, and the peak is followed by a decrease during the period between weaning and active feeding in the water. The white foetal coat remains fast in all pups up to a sculp weight of about 20 pounds, at which time the pup is about five days old. The percentage of fast-furred sculps then decreases steadily with increasing weight until, at a sculp weight of 53

pounds or more (two to three weeks of age) no fast-furred sculps are taken. The white coat moults by degrees, and usually has disappeared completely by March 30. The pups then are in the water a good deal and take the name of "beaters." The short hair coat possessed at this time, as was noted above, is at present a little more valuable than the white natal coat. They are, of course, scattered and harder to hunt at this stage.

MANAGEMENT NEEDS

At present there are no formal laws, international or otherwise, specifically governing the kill of harp seals in the northwest Atlantic. There are, however, annual conferences between government and industry in both Norway and Canada, and informal international conferences between government representatives of these two countries. Each year an informal agreement on starting dates for the hunting is made by them, to which the industry adheres.

Colman (1949), in reviewing the seal fishery up to 1948, concluded that there was little likelihood of danger from overhunting to the Newfoundland seal herds during the next 10 years. Certainly the kill statistics give ample evidence that the population is capable of maintaining itself at a rate of killing comparable to that in the 30 years previous to World War II (*i.e.* 159,000 per year, 16 per cent immatures and adults). In post-war years, however, the kill has increased to a level well over this. Not only is the kill of young more, but the kill of immatures and adults has almost doubled (Table 2). While for almost 20 years previous to 1912 there was an annual average kill of 249,000, only eight per cent of this was of immatures and adults. There has been almost a fourfold increase since then in the killing of these older seals in the moulting patches and there is no indication that it will lessen. This problem is more acute east of Newfoundland than in the Gulf of St. Lawrence where the total kill is relatively light. Most of the take of older seals in the Gulf is by shore-based nets. It is not practicable to reduce this kill since it involves local consumption of the seals by landsmen along the North Shore of the Gulf to whom seal netting is an important factor in the general living economy. It is not an expanding activity.

It must be remembered that the figures for the take of older seals east of Newfoundland represent only those recovered, not those killed. It is difficult to estimate the percentage loss of seals wounded, owing to variations in shooting efficiency, but in the past it has been quite high. A continuation of recent efforts to maintain a high standard of marksmanship with the use of high powered rifles will minimize the loss of wounded seals.

The industry still stands or falls on its catch of pups, however. The far greater commercial value of the young, and the preference of all operators to secure cargoes of young, point to the obvious desirability of protecting the maturing and breeding stock. The time taken to reach sexual maturity has been found to be long; eight years for the male and from five to eight for the female. Much of the present breeding stock consists of animals born between 1925 and 1943. This stock, which was produced and which matured during periods of relatively light hunting pressure on immatures and adults, is gradually passing out of the picture. It cannot be expected that it will be replaced by a stock of equal size from animals which are under a hunting pressure twice as great during the period of maturation.

Most of the shooting of older seals in the moulting patches takes place during the month of April, although the Norwegian ships often continue shooting on through May. The proportion of adult females, as stated above, becomes high only during the last few days of April. A closing date of April 30 for shooting would allow good hunting during the latter half of April, yet would provide some protection for breeding females.

The present opening dates of March 5 for the Gulf of St. Lawrence and March 10 for the east coast of Newfoundland were set to allow the taking of some fast fur as well as of pup fat. On the whole whelping begins and ends a few days earlier in the Gulf, and we strongly suspect that the two whelping groups are distinct. Fast white-coat fur apparently is still wanted. The opening dates allow a continued heavy take of pups, while they are still concentrated and vulnerable. A closing date under this set-up is desirable to protect the breeding females.

FUTURE OF THE INDUSTRY

The sealing industry recognizes that in terms of the Canadian economy it will never occupy more than a modest place. The necessity of working within very narrow economic limits makes it imperative that the highest possible quality of products be delivered. The great emphasis in the past in harp sealing has been upon quantity rather than quality. The days of the great catches are gone, however. It is the responsibility of the industry to make their sealing captains and and crews realize that quality must come first. The industry is aware of these things and much has recently been accomplished both in Newfoundland and on the mainland. There is still room for improvement in the handling and treatment of sculps from the moment of kill. An awareness of quality can be fostered among the crews by

uniformly basing their remuneration not on the quantity of seals brought in but on the market value. A carefully sculped, unoxidized pelt would result in a higher remuneration than two damaged oxidized pelts, and the oil, moreover, would be of a higher value.

There remains a possibility of a sustained kill of young seals of the present order only if the industry recognizes that it must protect the stock that produces these young seals, and lavish the utmost care upon what is taken. If *complete* protection were given to maturing and breeding seals, the production of young seals would build up under the present order of kill. But once the breeding stock is seriously down it will take years to recover. It remains to be seen whether this challenge for rational utilization will be adequately met.

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DISCUSSION

DISCUSSION LEADER SARGENT: Thank you, Dr. Dunbar, for a very interesting presentation. When I was in Newfoundland a few years ago, I recall a good deal of discussion about the need at that time for a regulation as respects the

harp seal and the difficulty of adopting regulations because of the international aspects that are involved. I wonder if you would care to comment on what regulations you presently have, and what hope there is for some sort of regulation that would perpetuate the seal harvest.

DR. DUNBAR: The only regulation that I am aware of at the moment is that there is a date before which it is illegal to kill the seals. It is in early March. It varies for the two different herds—March 8th or March 12th, or thereabouts, or the 5th or the 8th. It is in Dr. Fisher's paper. Dr. Fisher has recommended a closing date as well, and so far there is nothing down on paper internationally between Denmark, Norway, and so on concerning any other regulation.

There was a meeting in Copenhagen at the time that ICNAF met in 1952, in which the whole matter of the seal was discussed, and the Norwegians showed themselves to be very willing to cooperate. They are much fiercer on the herd than other nationalities are as a rule.

There is a gentlemen's agreement that Norway will no longer go north from the Newfoundland area after April and fill up their holds with migrating seals or with walrus in Davis Strait. The unspoken quid pro quo is that regulations on the actual sealing in Newfoundland will be taken easier for the time being. I think I am right in saying this and not treading on Dr. Kask's toes.

DISCUSSION LEADER SARGENT: The regulation regarding the opening of the season, then, applies only to the Canadians, or is it a gentlemen's agreement among other nations?

DR. DUNBAR: That is on paper. Right? That's the only thing we have on paper? The opening date, and it applies to everybody?

DR. KASK: Yes.

MR. CHARLES FREMONT [Quebec]: I would like to ask if the harp seal carries the *Porrocaecum*.

DR. DUNBAR: I think the answer is no. The *Porrocaecum* is not a common parasite in the harp seal. The harp seal has a very different habit of feeding from the harbor seal. It feeds on macroplankton. We have no evidence of any parasite host relationship between the harp seal and the harbor seal.

DISCUSSION LEADER SARGENT: Are there any further questions? I might ask one more myself. How is the fur of the pup used at the present time in the commercial markets?

DR. DUNBAR: I am on much less sure ground here. I think it is used largely for the trimming of ladies' coats and things, and for fur trimming on slippers, and that sort of thing. It is the most valuable item in the whole seal take, the skin of a white-skinned pup of two and a half to three weeks.

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Inhibition of Mold and Yeast Development in Fish Products

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Growth of molds and yeasts in smoked fish was strongly delayed when about 0.05 to 0.1% sorbic acid was incorporated in the flesh during the brining process. Development of "dun" in salted fish, which is caused by the mold Sporendonema epizoum, was likewise markedly inhibited by sorbic acid. Sorbic acid appears to be quite stable in fish muscle. Neither chlorotetracycline nor tetracycline was of any value in retarding mold or yeast development in such fish products.

Loss of quality of fish and fish products due to development of mold and yeasts is of far less frequent occurrence than that resulting from bacterial action. However, with some products such as smoked, salted, or dehydrated fish, storage conditions are frequently such that the moisture content may be quite adequate for mold development and yet tend to hinder bacterial growth. Since sorbic acid (SA) has proven a valuable fungistat for use with cheese *(8)* and is not injurious to health *(2)*, the possibility that it could be employed alone, or in conjunction with chlorotetracycline (CTC), to retard development of molds and yeasts in fish was investigated. A brief report concerning this investigation has already been published *(1)*.

EXPERIMENTS WITH SMOKED FISH

In the first experiment 20% (W/V) sodium chloride solutions, with and without the following additives, were prepared, the pH benig adjusted to approximately 7.0 to effect solution of the SA where necessary: SA 0.1 and 0.2%; CTC, 0.0005 and

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0.001%, and SA 0.1% + CTC 0.0005%. Pieces of fresh halibut *(Hippoglossus stenolepis)* approximately 3 x 3 x 1 in. in size were immersed for 15 minutes in the above solutions, drained and left exposed to air at room temperature for 2 hours. They were then smoked with oak smoke in a controlled tunnel for 6 hours at 20° C. and 70% relative humidity and stored at 4° C. in polyethylene bags. At regular intervals they were inspected visually for signs of mold development.

In a second similar experiment pieces of halibut, red spring salmon *(Oncorhynchus tschawytscha)* and sable-fish *(Anoplopoma fimbria)* were treated as in the first experiment, except that the SA concentrations used were higher (1.0 and 0.5%) and the immersion period in the brines was extended to one hour. In a third experiment pieces of sable-fish and halibut were treated by "dusting" their surfaces with powdered SA (1 g. per 800 g. fish) or by wrapping them in polyethylene sheets the surface of which had been sprinkled with SA (0.5 g./100 in.^{2}).

In addition to visual examination certain of the stored samples were subjected to direct bacterial counts *(9)* and to viable yeast and mold plate counts using "Difco" wort agar to which 5 p.p.m. of CTC had been added to inhibit growth of bacteria. Plates were incubated 5 days at 25° C.

Results obtained in the first experiment showed that the rather low concentrations of SA used and the rather short immersion time only retarded mold development on treated samples about 2 weeks in comparison with untreated samples. Pronounced mold growth had occurred on all samples in one month and the CTC treatment was without noticeable effect.

Much more promising results were obtained in the second experiment in which the samples were given a more prolonged immersion in stronger SA solutions. With these samples SA not only delayed or entirely prevented development of visible mold after 40 days at 4° C., but also effected a marked decrease in the population of viable molds and yeasts (Tables 1 and 2). Growth of neither molds nor yeasts was inhibited by CTC alone, and when it was used in conjunction with SA it usually reduced the effectiveness of the latter slightly. With sable-fish SA did not delay development of visible mold as markedly as with the other

TABLE 1

Inhibition of visible mold development in smoked fish by sorbic acid and chlorotetracycline

Concentration of preservative in brine (%)	Visible mold after 40 days' storage at 4° C.		
	Salmon	Halibut	Sable-fish
None	++++	+++	+++
SA, 1.0	−	−	+
SA, 0.5	−	−	+
CTC, 0.001	++++	+++	+++
SA, 0.5 + CTC, 0.0005	++	++	++

[1] Legend: − = None, + slight, ++ moderate, +++ marked, ++++ intense.

TABLE 2

Effect of sorbic acid and chlorotetracycline on growth of yeasts and molds in smoked fish

Concentration of preservative in brine (%)	Viable yeasts (Y) and molds (M): colonies x 10^6 per g.					
	Salmon[1]		Halibut[1]		Sable-fish[2]	
	Y	M	Y	M	Y	M
None	>200	>200	147	14	6.5	1.7
SA, 1.0		2.0		0.5	1.0	<0.01
SA, 0.5	0.5	1.0	0.06	<0.5	2.0	0.09
SA, 0.5 + CTC, 0.0005			36	0.7	3.5	0.03

[1] Stored 47 days.
[2] Stored 42 days.

fish, and this may have been because the high fat content of the fish reduced the amount of SA absorbed.

No mold growth occurred in 50 days in samples which were either treated with SA by the dusting procedure or which were stored in wrappers which were treated with the fungistat.

EXPERIMENTS WITH SALTED FISH

One of the common causes of spoilage in salted fish such as cod is the so-called "dun" which is caused by a halophilic brown mold *Sporendonema epizoum (4)*. This condition is difficult to control, and the measures which have been suggested *(3)* have not been particularly successful.

In the present investigation cultures of *S. epizoum* were isolated from a typical sample of "dun" salt cod by shaking a portion of the fish with 13% sodium chloride solution and streaking a loopful of the suspension over the surface of solidified Shoop's medium *(7)* in petri plates. Isolated colonies developed within 7 days and were transferred to agar slopes of the same medium and the spores which developed used in the following experiments.

Portions of lingcod approximately 2 x 2 x 0.5 in. in size were cut so that the skin was retained intact, and were dry salted by the "Kench" cure method *(5)*. The preservatives employed were incorporated into standard dairy salt by grinding in a mortar and finally blending thoroughly with a food mixer. Fish samples treated with salt alone or with salt containing incorporated SA, CTC or both (Table 3) were stored 5 days at 4° C. to ensure adequate salt penetration. The excess of salt was then scraped from the surfaces of the samples which were then sprayed with a light suspension of spores of *S. epizoum* in 13% sodium chloride solution. They were then stored in a cabinet at 25° C. and 75% relative humidity.

Four separate experiments were carried out, the samples being subjected to an almost daily visual inspection to ascertain whether "dun" discoloration had developed. The results (Table 3) show that 0.1 or 0.2% SA incorporated in the dry salt inhibited development of "dun" discoloration up to 60 days. The antibiotics CTC and tetracycline (TC) were ineffective when

TABLE 3

Effect of various preservatives in inhibiting development of "dun" in salted fish

Substance incorporated in dry salt (%)	Expt. 1 (fish stored 24 days)	Expt. 2 (fish stored 35 days)	Expt. 3 (fish stored 60 days)	Expt. 4 (fish stored 60 days)
None	++++	+++	+++	+++
SA, 0.05	+			+
SA, 0.10	−			−
SA, 0.20	−	−	−	
SA, 0.10 + CTC, 0.005			−	
SA, 0.10 + CTC, 0.010		+		
SA, 0.05 + TC, 0.01				+
SA, 0.2 + TC, 0.02	−			
Sodium benzoate, 0.05	+++			+++
+ NaH_2PO_4, 1.0	++			++
Sodium propionate, 0.1				+++
CTC, 0.01			+++	
CTC, 0.02		+++		
TC, 0.01				+++
TC, 0.02	+++			

Legend: − to ++++ as in Table 1.

TABLE 4

Recovery of sorbic acid from smoked halibut and sable-fish

SA concentration in brine (%)	Sample	Storage time in days at 4° C.	SA content in flesh (%)
None	Sable-fish	10	0.002
None	Sable-fish	40	0.001
1.0	Sable-fish	9	0.100
1.0	Sable-fish	9	0.105
0.5	Sable-fish	10	0.056
0.5	Sable-fish	10	0.048
None	Halibut	13	0.002
None	Halibut	13	0.003
1.0	Halibut	1	0.160
1.0	Halibut	5	0.140
0.5	Halibut	5	0.086
0.5	Halibut	6	0.088
0.5	Halibut	42	0.085
0.5	Halibut	42	0.091

TABLE 5

Recovery of sorbic acid from salted lingcod

SA added to dry salt (%)	Storage time in days at		SA content in flesh (%)
	0° C.	25° C.	
None	5		0.001
None	5		0.002
None		60	0.002
0.2	5		0.037
0.2		41	0.032
0.2		68	0.030
0.4	3		0.036
0.4	6		0.034
0.4	11		0.033

applied alone, and in most instances when used together with SA somewhat neutralized its beneficial effect. Sodium propionate and sodium benzoate plus NaH_2PO_4 *(3)* were almost or entirely ineffective in inhibiting "dun" development.

Sorbic Acid Content of Treated Samples

The amount of SA present in certain samples from the above experiments was determined as follows. Finely divided portions, 3 to 11 g. in weight depending on the SA content, were steam distilled in the presence of 50 g. of magnesium sulphate and 50 ml. of water and the SA determined spectroscopically in the distillate according to the procedure of Melnick and Luckmann *(6)*. Excellent recoveries were obtained in experiments in which known amounts of SA were added to fish samples.

The results obtained on analyses of certain samples of smoked and salted fish are recorded in Tables 4 and 5. They indicate that with the different procedures employed the fish contained only about 10 to 15% as much SA as was present in the brines used. In general the SA content of treated fish did not appear to decrease appreciably during the storage periods studied.

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Control of Eels in a Lake by Preventing the Entrance of the Young

by

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The American eel, *Anguilla rostrata* (LeSueur), is often a prominent species of sh, both in respect to number and size, in lakes of the Maritime Provinces of Canada. ince the eel is a predator on the eastern brook trout and competes with them for a ommon food supply, control of the numbers of eels in a trout lake is desirable.

The eel is catadromous. Thus, the best long-term measure to reduce and eventu-lly to eliminate eels from a lake is to stop recruitment to the limnetic population from he annual up-stream runs of young eels. In May, 1951, as a part of a program to ontrol the predators of trout (fish-eating birds, mammals and fish) at Crecy Lake, New Brunswick, a barrier was erected in the outlet in an attempt to keep out ascending els (Smith, 1955). The present article describes the barrier and presents observations n the movements and size of eels in relation to it.

The Barrier

In the construction of an eel barrier it is of prime importance to channel *all of the vater* through a spillway so as to provide a clear fall into the bed of the stream below. Young eels are by nature persistent in their up-stream migrations, and, being well adapted by their shape (Figure 1), will work their way through surprisingly small penings to pass an obstruction, Thus, if the wall of the barrier is not made water-ight, all leakages should at least be screened.

The barrier erected in the outlet of Crecy Lake is illustrated in Figure 2. The wall of the barrier consists of spruce boards, one inch in thickness, nailed vertically o a frame of 2-inch x 2-inch scantling. By excavating a trench, the wall was extended pproximately 20 feet into both banks of the stream. The boards, with sharpened nds, were driven into the ground before being nailed to the frame. The up-stream ace of the boards was covered with copper fly-screening. On the down-stream side, n apron of this screening was also attached to the boards at the lowest level possible, nd then covered with clay and gravel when the trenches were filled and when the ed of the stream was built up at the wall of the barrier. The wings of the wall roject from 1 to 1½ feet above the ground level.

The water discharges over a sluice 4½ feet wide and 7 feet long, constructed of ongue and groove lumber (Figure 2). The sides of the sluice are 9½ inches high. The down-stream end of the sluice is hung by iron rods from a timber laid on posts which are set into the banks of the stream. There are no supports from the bed of

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the stream. The water falls about $2\frac{1}{2}$ feet at usual summer levels. The bed of the stream under the sluice was filled with gravel to above the summer water level.

The barrier described is of the simple construction and modest proportions necessary to accommodate a small stream (Figure 2) discharging 5 to 1200 cubic feet per minute. Larger streams will require larger structures. The Crecy Lake barrier embodies features which should be simulated in attempts to deal with larger streams.

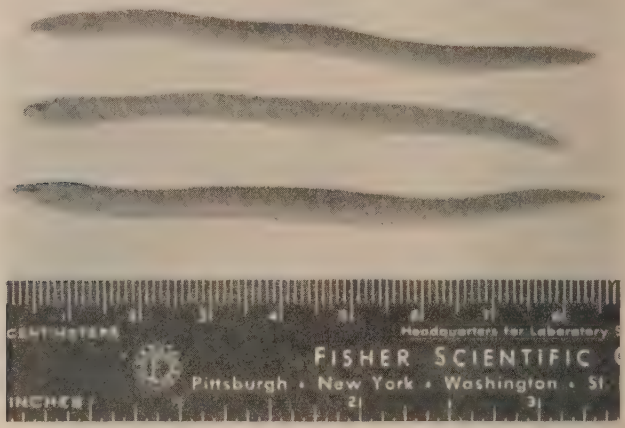


Figure 1. Young eels from Crecy Lake outlet.

Movements of Young Eels in Relation to the Barrier

Seasonal

Young eels have been observed below the barrier in Crecy outlet from mid-May through September. In 1954, from June 4 to September 28, eight samples of eels were collected from the stream below the barrier (Figure 3). They were taken in a fine-meshed net after treating the water with "Creolin" (coal-tar disinfectant). This chemical drove the eels from hiding places on the stream bottom. Those not collected were driven down-stream. In any event, this procedure depopulated the water below the barrier only temporarily. Young eels continued to move up to the barrier throughout the summer period. Since the samples alone removed a good proportion of the local population, new individuals were apparently involved in the subsequent up-stream movements.

The number of eels below the barrier became less by September. As the fall progressed, they almost disappeared from the area. There was no evidence that the young eels remained over the winter in the stream, at least for some distance below the barrier.

Diurnal

It has been widely observed that eels are most active at night. The young eels below the Crecy barrier followed this pattern of behaviour. For the most part, they remained hidden in the gravel on the bottom of the stream during the day.

ffect of water temperature

The eel is a warm-water species, becoming inactive at low water temperatures, ven to the extent of "hibernating" during the winter, buried in the mud (Adams and Jankinson, 1928). The period, mid-May through September, when young eels were bserved to move up Crecy outlet, coincides quite closely with water temperatures bove 12°C. in that stream. The seemingly strong influence of only a moderately low vater temperature in curtailing the up stream movements of the young eels has much ignificance in the operation of an eel barrier. Apparently there is little need for oncern about young eels by-passing a barrier during the high-water periods of spring nd fall, or during the winter, when control of water flow is most difficult.

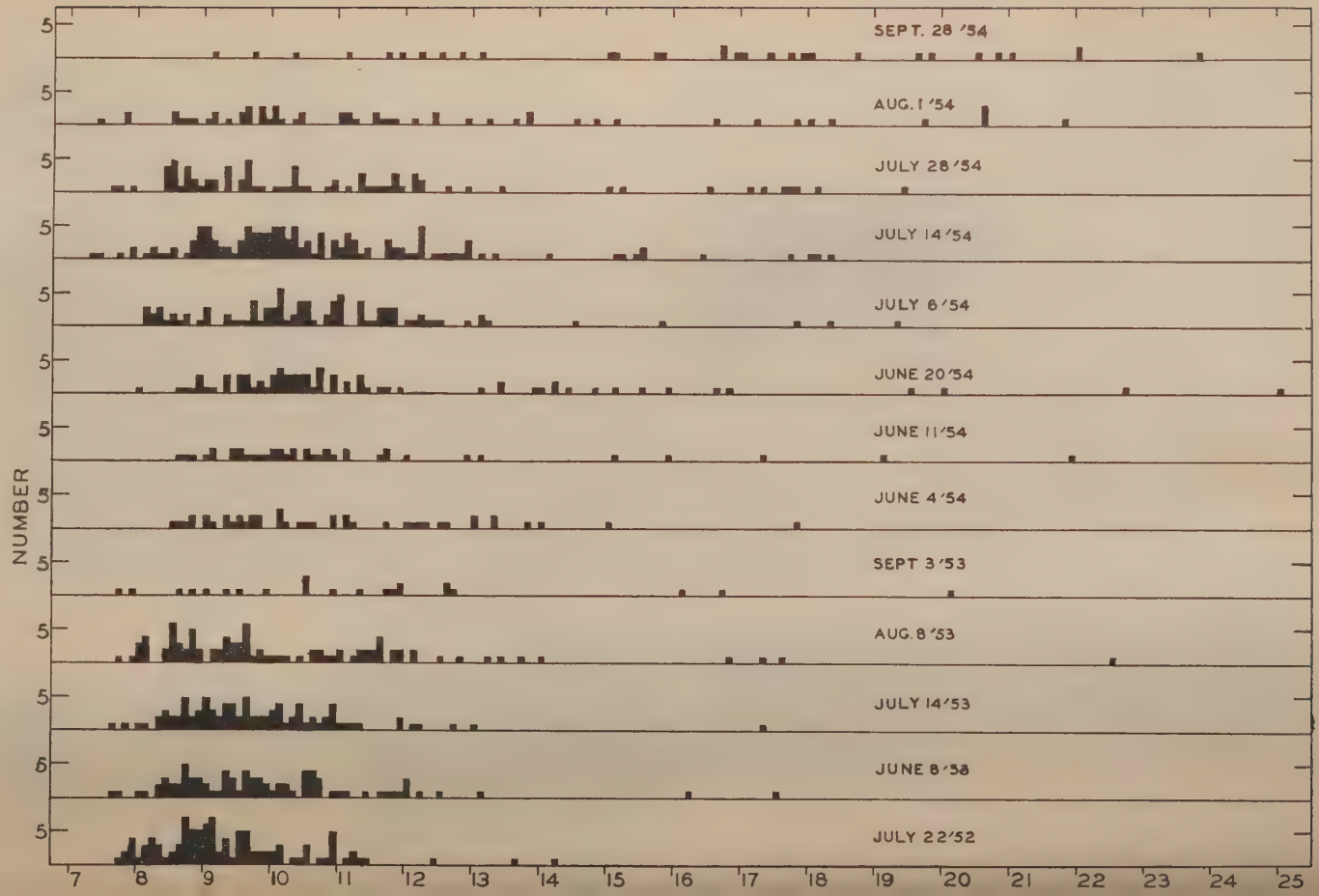
Movements over land

Young eels will leave the water to move over wet surfaces in attempts to surmount n obstruction to their up-stream migration. On three occasions since the barrier was onstructed in Crecy outlet in 1951, young eels have been observed to leave the stream ed. These movements occurred during exceptionally heavy rains. On August 9, 951, August 18, 1952, and August 15-16, 1953, when the rainfall was 4·66, 2·87 and ·65 inches respectively, the eels moved up the rather steep banks of the stream to the djacent ground (Figure 2). Whether these eels would have found their way around

Figure 2. Eel barrier in Crecy Lake outlet.

Looking up-stream to the barrier.

Looking across the barrier.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he wings of the barrier remains a question, however, since their overland movements were effectively checked by treating the ground with "Creolin".

That young eels will act in the above fashion casts some doubt upon the effectiveness of a barrier to prevent their entrance into a lake. Certain observations at Crecy Lake, however, are reassuring. The eels left the stream only immediately below the barrier, that is at the point where they could no longer advance up the stream. Probably the screening of only a restricted area of the stream's banks is required to stop the overland movements. Further, observations suggest that young eels detect and move against the weak currents in surface seepages which enter a stream from the contiguous land during heavy rains. If the seepage arises only from rainfall, and involves no overflow from the stream above, it appears improbable, providing the above observations are generally applicable, that the eels would be "directed" around a barrier.

Size of Eels

The length frequencies among the eels collected below the barrier in Crecy outlet are shown in Figure 3. The length of the longest eel collected was 25·0 centimetres. None of appreciably larger size were observed. The majority were under 12 centimetres in length. Undoubtedly two or more year-classes are represented in the samples, but the smaller individuals were likely those that had entered fresh water earlier in the current year.

Comments

The eel is long-lived in our fresh waters (Smith and Saunders, 1955). The large eels that migrate at approaching maturity from Crecy Lake in the fall are, in the majority, six to eight years of age. It follows that the barrier to exclude the young eels will reduce the lake population only progressively over a number of years. As yet only the abundance of the younger year-classes will have been affected. We do not have information on the status of these younger year-classes in the lake. The effectiveness of the barrier will be best gauged from the numbers of larger eels that migrate from the lake during the next few years. In the meantime, however, careful observations by a technician resident at Crecy Lake throughout the year all point to the success of the barrier in keeping out the young eels.

Immediate and long-term control of eels may conceivably be realized by poisoning those present in a lake and by the construction of a barrier in the outlet to exclude the young. This dual action was not taken at Crecy Lake since poisoning of the trout would have disrupted investigations there in progress on that species (Smith, 1955)

The assistance of Mr. G. Curtis Lowery in the field and Miss Mary Holmes in the laboratory is gratefully acknowledged. This paper is published with the permission of the Fisheries Research Board of Canada.

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Standing Crops of Trout in a Small Prince Edward Island Stream*

by

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A fortunate combination of fertility, coolness of water, good spawning conditions and little competition from other species of fish results in a favourable habitat for the eastern brook trout (*Salvelinus fontinalis* (Mitchill)) in Prince Edward Island streams. A study of the population and movements of trout in Ellerslie Brook is in progress (Smith, 1951a, b). Information is sought for the most effective management of the fishery in this stream and others of the Maritime region. As a part of the study, annual assessments are made of the trout population in a number of sections of Ellerslie Brook system. Data are presented herein for late-summer standing crops of trout in a 450-yard section of Hayes Brook, tributary to Ellerslie. Data are available for eight years. They are presented in the nature of a progress report awaiting analysis of those for the entire Ellerslie system.

Hayes Brook

Unless otherwise noted, reference to "study area" will signify the 450-yard section of Hayes Brook in which the population assessments were made. This section runs upstream from the confluence of Hayes and Ellerslie Brooks (Figure 1).

The study area varies in width from three to four feet in summer. The average depth of water approximates three inches. However, pools, some to a depth of two feet, occur where logs and other obstructions deflect the flow of water. Shrubbery, principally alder, trees and other vegetation provide heavy cover along and over the stream (Figure 2).

Much of the stream bed consists of weathered sandstone in the form of sand to small stones. There is some admixture of organic materials, but generally the bottom is firm. Spawning facilities for trout are moderately good.

Hayes Brook receives drainage from springs. There results a cool environment throughout the summer. Only during the warmest weather does the water temperature reach and exceed 20°C. (68°F.) (Table I). The water is moderately alkaline (pH. 7·7 on July 20, 1952).

The fish population consists entirely of brook trout except for an occasional stickleback and small eel. The little angling that is done is restricted to a pool at the head of the study area. Probably the most serious predator of the trout has been the mink. Cannibalism undoubtedly occurs, but has not been studied.

*Read at the meetings of the Northeast Section of the American Fisheries Society, Atlantic City New Jersey, March 23-25, 1955.

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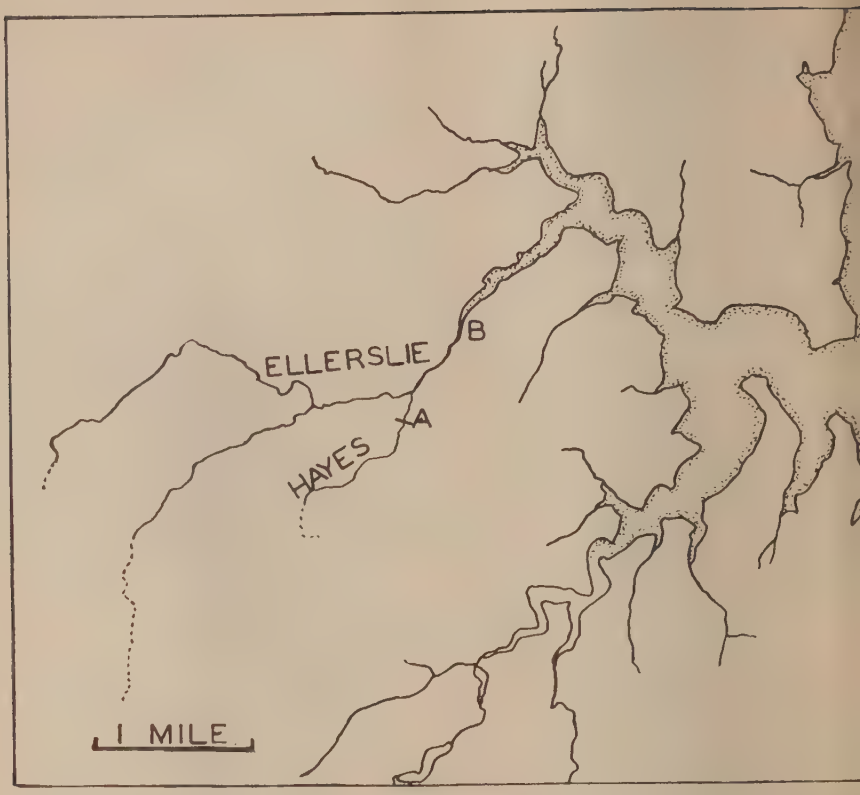

Figure 1. Map of Ellerslie Brook. A—assessment area on Hayes Brook. B—location of two-way fi trap at the head of tide.

Figure 2. Views of Hayes Brook. A—September 3, 1950 (by H. V. Pritchard); B—December 3, 195

Table I

Temperature records for Hayes Brook

Date	Temperature, °C.	
	Air	Water
1949		
June 19	20·9	19·7
27	16·9	12·7
July 10	21·7	15·3
24	19·3	15·9
Aug. 7	29·9	20·5
21	22·0	15·6
1950		
June 10	26·8	17·2
24	15·3	9·9
July 9	18·9	15·4
22	15·5	14·1
Aug. 5	21·0	16·1
26	21·2	16·3
1952		
July 16	25·2	18·2
20	20·0	15·8

Sea-run Trout

Trout in Ellerslie Brook, in common with those in other streams of the area, may run to salt water and periodically return. The sea-running propensity has to be borne in mind in a study of the trout population of any part of the Ellerslie system such as the study area in Hayes Brook. It is pertinent to note that the majority of the trout making their first run to salt water are age II.

Methods of Assessment

Estimates of the standing crops of trout in Hayes Brook were made either in late August or early September of each year from 1947 through 1954. An exception was in 1949 when the estimate was made in July.

Schnabel-type estimates were made from 1947 through 1950 (Schnabel, 1938). From 1951 through 1954, capture of all trout in Hayes Brook was attempted by electrofishing. Repeated tests in sample areas in the Ellerslie system were consistent in showing that over 90 per cent of the trout could be captured by this method (Saunders and Smith, 1954). The study area was closed by barrier nets to prevent the inward and outward movements of trout during the assessment periods. The disturbing influence of recruitment upon the methods of estimate was thus avoided. The time taken for the estimates did not exceed five days. In consequence, natural mortalities during the time involved were probably not serious. A numbered strap tag was fastened around the lower jaw of each older trout. Fingerlings (age 0) were marked only by the removal of the adipose fin, except in 1952 when the left ventral fins were also clipped.

Information on movements of tagged trout that left the study area in Haye Brook was obtained from three sources: (1) two-way fish traps maintained just belov the confluence of Hayes and Ellerslie Brooks and at the head of tide, (2) populatio studies on other sections of the Ellerslie system, and (3) creel censuses.

Size and Age of Trout

From 1949 through 1954, the fork length of each captured trout was recorded i centimetres. Length frequencies of the trout in the standing crops for the severa years are shown in Figure 3. In 1949 and 1950, approximately 70 and 60 per cen respectively of the estimated numbers of trout in the standing crops were measure In later years over 90 per cent of the trout were captured by electrofishing an measured.

Age determinations by scale reading were not made for trout from the study area From the grouping of the length frequencies, however, it was possible to set off th fingerlings from the older trout quite well. Any trout with a length below eigh centimetres (3·2 inches) was classified as a fingerling. In 1952 the fingerlings in th study area were marked by the removal of the left ventral fins. This mark distinguishe them from any other marked fingerlings in the Ellerslie system. When 36 of thes differently-marked fingerlings were captured and measured in the study area in 1953 a yearlings, they had an average length of $10 \cdot 8 \pm 1 \cdot 19$ centimetres ($4 \cdot 3 \pm 0 \cdot 47$ inches) By reference to Figure 3, it is apparent that there was more than one age class among th trout over eight centimetres in length. At the same time, however, we may conclud that the majority of these trout were of ages I and II. Yet, since age determination were not made trout over eight centimetres will be grouped and designated as olde trout.

Standing Crops of Trout

Data for the numbers of trout in the summer standing crops are presented i Table II. As may be seen, the numbers of trout fluctuated considerably from yea to year.

Table II

Standing crops of trout in Hayes Brook

Year	Number		
	Total	Fingerlings	Older Trout
1947	939 - (834-1042)*	588	351
1948	1017	729	342
1949	818 (722-948)*	539	279
1950	544 (437-645)*	321	223
1951	584	166	418
1952	983	611	372
1953	670	308	362
1954	762	468	294
Mean	796	466	330
s	191·6	187·6	61·5
Coefficient of variation (%)	24·1	40·3	18·6

* Poisson limits of 95 per cent confidence (Ricker, 1948).

The mean of the standing crops of all ages of trout in the study area (approximately 600 square yards) for the eight-year period was $796 \pm 191 \cdot 6$ individuals. Expressed on an area basis, it approximated 13 trout per 10 square yards. The weight of the trout was calculated from the length-weight relationship; $W(gm.) = 0 \cdot 009585\ L(cm.)\ 3 \cdot 097$. This relationship was established for other trout from Prince Edward Island over a length range from 15 to 35 centimetres (6 to $13\frac{1}{2}$ inches). The mean standing crop of trout of all ages approximated 20 pounds in the study area or 170 pounds per acre.

These data illustrate a high level of trout production. Only in a few instances have higher standing crops of brook trout been reported for American streams (Carlander, 1950).

Presenting only the mean standing crop for the entire population masks relationships between the stocks of fingerlings and older trout. The mean standing crop for fingerlings was $466 \pm 187 \cdot 6$ and for older trout $330 \pm 61 \cdot 5$ (Table II). Coefficients of variation in the numbers in the standing crops were $40 \cdot 3$ for the former and $18 \cdot 6$ for the latter. Annual fluctuations in the numbers of fingerlings were appreciably greater.

Maintenance of Standing Crops

In 1950 and 1951 the number of fingerlings in the study area was insufficient to provide the numbers of yearling trout in succeeding years (Table II). This was also true for all of the years unless there was a high survival of fingerlings to yearlings. We have evidence that this was not the case even when the number of fingerlings was large. As previously noted, the 611 fingerlings present in 1952 were distinctively marked by the removal of the left ventral fins. Records obtained in 1953 show that only 38 of these ($6 \cdot 4$ per cent) survived to the study area as yearlings. It is apparent that population of older trout could only have been maintained by movements into the study area.

In the years 1952, 1953 and 1954 the populations of older trout were 372, 362 and 294 respectively (Table II). Of these, 203, 251 and 121 in the respective years were unmarked and accordingly were new to the area. It was also found that of the trout new to the area, 122 in 1952, 203 in 1953 and 24 in 1954 were in the length range $8 \cdot 1$ to $13 \cdot 0$ centimetres and were thus, for the most part, yearlings. Since the annual population assessments were made in late summer these trout had entered the study area as advanced fingerlings or as yearlings.

Trout also moved from the study area. From 1949 through 1952, 1,197 older trout were tagged in the area. Of these, 209 were recaptured in Ellerslie Brook in traps, by angling and during population studies.

Since survival of fingerlings to yearlings was low, and there were extensive movements into and out of the study area, it is not surprising that fluctuations in the numbers of fingerlings in the standing crops were so poorly reflected in the numbers of older trout in succeeding years (Table II). However, our observations show clearly that fingerling production elsewhere in the Ellerslie system was sufficient to maintain the population of older trout in the study area.

Only a few of the large numbers of trout fin-clipped and tagged in contiguous areas of Ellerslie Brook in other population studies moved upstream into the study area of Hayes Brook. Records from the trap at the mouth of Ellerslie Brook reveal that trout from the study area in Hayes Brook have run to salt water. Numbers of these have come back into Ellerslie Brook, but only exceptionally into the study area in Hayes. It is reasonable to conclude that the annual recruitment of unmarked older trout to the study area was largely from the trout population higher in Hayes Brook. The upper reaches of Hayes Brook support a good number of fingerlings but no trout were marked there. It is a very small stream and habitats for older trout in summer are limited. To a large extent maintenance of the numbers of older trout in the study area reflected a progressive downstream movement of trout with increasing size.

Delimiting Factors

Fingerlings and older trout in the study area occupied, for the most part, separate habitats in late summer. Most of the fingerlings were taken in shallow riffle areas and the older trout in the deeper water where there was suitable cover for hiding.

Apparently the factors that determined the numbers of both fingerlings and older trout in the study area operated with varying intensity over the eight-year period. However, there was less annual fluctuation in the numbers of older trout in the summer standing crops than that exhibited by the fingerlings. This situation was probably to be expected. Not only were the numbers of fingerlings dependent upon the extent and success of spawning, but also upon adverse environmental factors, such as restriction in habitat with lowering water, with which the fingerlings were probably less able to cope than the older trout.

Observations made during the population assessments demonstrated clearly that the older trout in the study area were closely associated with hiding places in their habitat. This association was so marked that we were able, from year to year, to anticipate the places in the study area occupied by older trout. On numerous occasions captured trout, when released, were observed to return to the particular place from which they had been removed. It was apparent from our observations that older trout occupied a particular type of habitat and were distributed in it in relation to suitable hiding places.

The close association of older trout with hiding places suggested strongly that availability of these was a dominant factor in delimiting the standing crops of older trout.

Over the period of the investigation no marked change was observed in the number of hiding places suitable for older trout. Actually older trout were taken almost entirely in the same spots from year to year. We have concluded that the constancy in the number of hiding places was reflected in the relative constancy in the numbers of older trout in the annual standing crops.

Fish-Cultural Implications

Trout production in the study area of Hayes Brook was high. Reference to Figure 3 shows that this production, in keeping with the small size of the stream, was mainly of small trout. The legal size limit for angling trout on Prince Edward Island

was a fork length of six inches (15·2 centimetres) during this study. Thus only a small proportion of the trout in the study area were of immediate value for angling. In 1955 the size limit was removed. The importance of the area, and others of a comparable character in the Ellerslie system, is its role as a nursery for small trout. It is these trout that support the sport fishery in Ellerslie Brook and its estuary.

The supply of fingerlings in the study area was inadequate, either as a result of movement from the area or deaths, to maintain the observed standing crops of older trout. Movements of trout into the section, however, supplemented the population. Natural reproduction in the Ellerslie system appeared adequate. Need for supplementing the natural reproduction by stocking with fingerlings was not indicated by our study. Neither would the introduction of older trout be helpful, since the living space for older trout appeared quite fully utilized.

The carrying capacity for older trout in the study area was closely associated with hiding places. An increase in the number of hiding places by stream improvement in this direction would appear to be a feasible method of raising the number of older trout.

Summary

1. Summer populations of brook trout in a 450-yard section of Hayes Brook, tributary to Ellerslie Brook, Prince Edward Island, were assessed annually over an eight-year period.
2. Hayes is a nursery stream, 3 to 4 feet wide and averaging three inches in depth in the assessment area at summer levels, with few trout over seven inches in length.
3. The mean of the numbers of trout in the standing crops over the eight-year period was, for the entire population, $796 \pm 191 \cdot 6$; for fingerlings $466 \pm 187 \cdot 6$; and for older trout $330 \pm 61 \cdot 5$. This was a high level of production.
4. Annual fluctuations in numbers of fingerlings were not comparably reflected in the numbers of older trout. The carry-over of fingerlings in any year was insufficient to provide the standing crops of older trout. The number of older trout was largely maintained by downstream movements.
5. Availability of suitable hiding places was a dominant factor in delimiting the carrying capacity for older trout. Alteration of the habitat to provide more hiding places is indicated as a management procedure to increase the number of older trout.

Acknowledgments

The population assessments were made in 1947 by E. L. Cox, in 1948 by R. V. Scott, in 1949 and 1950 by H. V. Pritchard, and in the later years by J. W. Saunders. The assistance in the field of C. R. Hayes, Cyril Williams and Harold Ross is gratefully acknowledged. This paper is published with permission of The Fisheries Research Board of Canada.

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Density Inversions in Canadian Eastern Arctic Waters

Among the hydrographic results of the *Calanus* expeditions of 1949–51 in Ungava Bay, Hudson Strait and Frobisher Bay, sponsored by the Fisheries Research Board of Canada, are twenty-two instances of density inversion showing unstable conditions in the sea. They were observed at twenty stations (two stations showing inversion at two different depths) out of a total of forty-eight stations occupied during the three seasons. Six of the inversion stations were in Ungava Bay, one in the Button Islands north of Cape Chidley, four in Hudson Strait between Wakeham Bay and Lake Harbour, and the remainder in Frobisher Bay.

Such instabilities, appearing in oceanographic results in the past, have usually been looked upon as fictitious, and attributed to errors in thermometer readings, sample labelling, titration or filing of results. In the present instance, titrations have been repeated where possible, and the methods used on board ship seem to preclude the possibility of other errors. Recently, Spilhaus *et al.*[1] have recorded similar inversions in the waters just south of Cape Cod, and have given evidence of some correlation of the times of observed instability with the times of lunar transit. I am informed by Dr. Carsola (personal communication) that inversions of short duration are common in shallow-water observations in progress at the U.S. Navy Electronics Laboratory at San Diego, and Dr. John Tait, of Aberdeen, has reported (at the 1952 meeting of the *Conseil Permanent* in Copenhagen) some more or less persistent instabilities observed during work in the Faero-Shetland Channel. There is a published record of another example, in the Okhotsk Sea, from the nineteenth century[2], and the *Michael Sars* expedition of 1910 found a density inversion at one station in the Atlantic (28° 37′ N.; 19° 08′ W.)[3].

The *Calanus* observations have been related to the state of the tide in each instance and are plotted on a tidal clock in Fig. 1. Tests (χ^2) comparing the radial scatter of the stations with inversions, those without, and of all stations, respectively, with an equally distributed radial pattern, give the P values shown. The latter two observed distributions are reasonably close to a random scatter, as would be expected; but the distribution of the instabilities verges on disagreement with random scatter, and the

Fig. 1. A twelve ½-hour tidal clock, showing the times, with respect to tide, at which stations with density inversions (black circles) and without density inversions (open circles) were occupied. The P values are explained in the text: ●, $P = 0{\cdot}065$; ○, $P = 0{\cdot}345$; ● + ○, $P = 0{\cdot}565$; *S.E.*$\bar{d}$, $P = 0{\cdot}055$

P value for the comparison of the means (standard error of the difference of the means) of the inversion and non-inversion stations is on the margin of significant disassociation (difference is 2·02 times its standard error). It is, moreover, at once apparent on examination that, of the twenty inversion stations, half lie in one quadrant, in the first three hours of the ebb tide.

The establishment of these unstable conditions, even for the short periods of time during which they probably exist, obviously requires considerable forces, which are apparently to be found in the extreme tidal movements of the area. Hudson Strait tides are very high (33 ft. at Ashe Inlet), the mean spring tide interval at Frobisher Bay is 32½ ft., and a tide of more than 50 ft. has recently been recorded at the head of Ungava Bay.

The details of this work will appear in full in due course.

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Montreal. April 6.

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The oxidation of propionic acid by a marine bacterium

During the course of an investigation of the metabolism of bacteria of marine origin, one of them, designated B16 and tentatively identified as a species of *Mycoplana*[1], was found to exhibit unusual behaviour in its oxidation of propionic acid. In view of the several reports which have appeared recently regarding the metabolism of propionate in mammalian tissues[2,3,4,5,6], the present observations, although of a preliminary nature, appeared to be worth recording.

In Table I are presented data, based on oxygen uptake determined by the use of conventional Warburg respirometer techniques, showing the rate and extent of oxidation of several compounds by resting cell suspensions of B16 grown in various media. The endogenous oxygen uptake has been subtracted from that observed in the presence of added substrates in calculating the values recorded. While this procedure cannot be completely justified on the basis of the data available, a consideration of the course of oxygen uptake by resting cells with several different quantities of compounds such as acetate, pyruvate, propionate, or succinate as substrates, lead to the conclusion that it was probably the correct one in this instance, as the oxygen uptakes observed were closely proportional to substrate available only when the endogenous uptake was subtracted. In any event, in all instances where oxygen uptake was less than that expected for complete oxidation of the substrate, with the exception of the oxidation of acetate and butyrate by cells grown in either nutrient broth-yeast extract or succinate medium, all rates of oxygen uptake had decreased to that of the endogenous control before oxygen equivalent to the theoretical amount needed for complete oxidation of substrates to carbon dioxide and water had been consumed, whether the endogenous uptake was subtracted or not. This decrease in rate of oxygen uptake to that of the endogenous control was not due to enzyme inactivation but apparently to substrate exhaustion, as the addition of fresh substrate resulted in the immediate resumption of oxygen uptake at an increased rate. It is thus evident that while cells grown in any of the media oxidize acetate, pyruvate, *dl-iso*citrate, succinate, and butyrate with the uptake of less than the theoretical amount of oxygen necessary for their complete oxidation, and cells grown in nutrient broth-yeast extract medium oxidize propionate to a similar extent, cells grown in synthetic media with either succinate or acetate as sole carbon source oxidize propionate with the uptake of the theoretical amount of oxygen for its complete oxidation. The R.Q. for this apparent complete oxidation was determined and found to be 0.85 (calculated value, 0.857). Although not shown in the table, cells grown in synthetic medium with propionate as sole carbon source resembled those grown in nutrient broth-yeast extract medium in their oxidative behaviour toward the compounds considered; while cells grown in a medium with citrate as carbon source resembled those grown in acetate medium.

TABLE I

COMPARISON OF THE RATE AND EXTENT OF OXIDATION OF VARIOUS COMPOUNDS BY WHOLE CELLS OF THE MARINE BACTERIUM B16 HARVESTED FROM THREE DIFFERENT GROWTH MEDIA

Each Warburg cup contained 0.133 m*M* phosphate buffer, pH 6.7, 5 μM substrate (10 μM *dl-iso*citrate), and washed cells equivalent to 1 mg cell nitrogen in a total vol of 2.8 ml of artificial sea water[1]. 0.2 ml 20% KOH in center well. Gas phase air. Temperature 25°. Substrate added after 15 min temperature equilibrium.

*Growth medium**	*Nutrient broth-yeast extract*			*Succinate*			*Acetate*		
Substrate	$Qo_2{}^{N}$**	% *oxidation****	*Time§ min*	$Qo_2{}^{N}$	% *oxidation*	*Time min*	$Qo_2{}^{N}$	% *oxidation*	*Time min*
Acetate	220	77	55	134	76	75	820	65	29
Pyruvate	312	37	40	225	40	50	820	50	29
*dl-iso*Citrate	272	36	50	480	46	50	210	40	100
Succinate	272	47	50	576	62	50	182	48	100
Propionate	404	66	55	252	100	160	247	100	158
Butyrate	300	80	90	97	85	320			

* The medium consisted of an inorganic salt solution plus the organic material indicated.

** $Qo_2{}^{N}$ is expressed in μl O_2/hour/mg cell N, and is based on the most rapid rate of oxygen uptake observed.

*** Calculated on basis of theoretical oxygen uptake required for complete oxidation of 5 μM of substrate to CO_2 and H_2O.

§ The length of time required for the rate of oxygen uptake to decrease to that of the endogenous control following the addition of substrate.

The data imply that cells grown with acetate (or citrate) as sole carbon source do not oxidize propionate solely *via* succinate, either through preliminary condensation of CO_2 with propionate to yield succinate directly[4,5], or *via* the intermediate formation of *iso*succinate[3,4], for the rate of oxygen uptake with propionate as substrate exceeds that with succinate, which should not be possible if the rate of oxygen uptake with propionate as substrate is limited by some oxidative step(s) subsequent to succinate. If , however, the rate of oxidation of succinate when succinate was the substrate was limited at some point prior to the first oxidative step, such as by cell permeability or substrate activation, then the difference in rates of oxygen uptake could occur, but such a limitation cannot account for the result, as succinate is in fact utilized more rapidly than is propionate, even though cells from the acetate medium take up oxygen more rapidly when attacking propionate than succinate.

Whether or not propionate is oxidized *via* pyruvate through the mechanism proposed by MAHLER AND HUENNEKENS[2] in cells grown in synthetic media with succinate, acetate, or citrate as carbon sources cannot be determined from the data available.

The complete oxidation of propionate has been observed in this study only under conditions of greatly reduced rate of utilization of substrate and hence might be due to a slower rate of entry of propionate than of those compounds only partially oxidized into a common enzyme system. That this is unlikely, however, is evident from the fact that butyrate is utilized even more slowly than propionate and yet is only partially oxidized (Table I).

Evidence has been obtained that is consistent with the view that a conventional tricarboxylic acid cycle is present in this organism[7]. The results reported here indicate the possible existence of an alternate system for the complete oxidation of propionate.

The whole cell preparations used in this work oxidize *d*-lactate, *dl*-lactate, glycolate, malonate, oxalate, and formate at an extremely low rate, if at all.

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Contributions to the Life-history of the Sockeye Salmon

[PAPER 40.]

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APPENDICES

CONTRIBUTIONS TO THE LIFE-HISTORY OF THE SOCKEYE SALMON (No. 40)

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INTRODUCTION

This is the fortieth report in a series reporting on the sockeye in the commercial catch in the main runs north of the Fraser River. The data are those for the commercial fishery and do not necessarily represent the escapement, as was shown in No. 38 of this series. We have a record only of the age composition of the catch and not of the escapement which gives rise to our future runs. The implications of this situation on our attempts to predict these future runs are not understood, since we do not yet know to what extent hereditary and (or) environmental factors determine the age at which sockeye mature. This year for the first time the numbers of fish caught, as published by the Statistical Branch of the Department of Fisheries at Vancouver, are being added to the tables to supplement the pack figures.

DESIGNATION OF AGE-GROUPS AND TREATMENT OF DATA

Two outstanding features in the life-history of the fish have been selected in designating the age-groups—namely, the age at maturity and the year of its life in which the fish migrated from fresh water. These are expressed symbolically by two numbers—one in large type, which indicates the age of maturity, and the other in small type, placed to the right and below, which signifies the year of life in which the fish left fresh water. The age-groups which are met most commonly are:—

3_1, 4_1—the "sea types" or fish which migrate seaward in their first year and mature in their third and fourth year respectively.

3_2—"the grilse," almost exclusively males and frequently called "jacks," which migrate seaward in their second year and mature in their third year.

4_2, 5_2—fish which migrate seaward in their second year and mature in their fourth and fifth years respectively.

5_3, 6_3—fish which migrate seaward in their third year and mature in their fifth and sixth years respectively.

6_4, 7_4—fish which migrate seaward in their fourth year and mature in their sixth and seventh years respectively.

Fish were measured to the nearest quarter of an inch, but when averaged the average has been recorded to the nearest tenth of an inch to avoid using fractions of more than one decimal place. Weights were taken to the nearest tenth of a pound. This has resulted in an even-pound and half-pound bias when the data are grouped to the nearest quarter-pound.

1. THE NASS RIVER SOCKEYE RUN OF 1954

(1) General Characteristics

The catch of 101,600 sockeye* which yielded a pack of 10,285 cases was below the averages of the past five- and ten-year periods, which produced packs averaging 21,723

* This figure, taken from the British Columbia catch statistics of the Federal Department of Fisheries, Vancouver, is to the nearest 100 pieces.

and 16,814 cases respectively. The pack was, however, slightly better than that of 1949, which was the parent year for 60 per cent of this year's catch. The escapement is reported to have ranged from poor to light.

(2) Age-groups

As indicated above, 60 per cent of the Nass River fish sampled were in their fifth year (Table I). Of these, two-thirds had spent two years in fresh water and one-third one year. Thirty-five per cent of the catch sample were four-year fish which had spent one year in fresh water, and the remaining 5 per cent of the sample consisted of fish in their sixth year which had spent two years in fresh water. One 4_1 female was present in the catch sample (Tables II and III).

(3) Lengths and Weights

The Nass River sockeye were very large, with the 4_2 males and the 5_3 males and females showing a slight increase on previously recorded lengths and most groups showing slight increases over previous weight records (Tables II to V).

(4) Distribution of Sexes

The sockeye had normal sex ratios for this population, with a slight excess of females for each age-group (Table VI). The 4_2 fish, with a ratio of 42 males to 58 females, showed a ratio very close to that in the cycle-year (Table VI). The over-all ratio was 43 males to 57 females.

2. THE SKEENA RIVER SOCKEYE RUN OF 1954

(1) General Characteristics

The Skeena River sockeye-catch of 571,900 fish,* giving a pack of 60,817 cases (Table VII), was 10,000 cases below the average pack of the previous five- and ten-year periods. It was slightly below the pack of 1949, the cycle-year for the 5-year-old fish, but higher than the pack of 1950, the cycle-year for the 4-year-old fish. The escapement is reported to have been about average for this system.

(2) Age-groups

Five-year-old fish formed 64 per cent of the Skeena catch sample, 54 per cent being 5_2 fish and 10 per cent 5_3 fish. Thirty-three per cent of the sample was 4_2 and 2 per cent 6_3 fish. That there is no outstanding variation from normal is readily seen in Table VII.

(3) Lengths and Weights

The most numerous age-group, the 5_2 class, averaged longer and heavier than populations in the past. The other group in their fifth year, the 5_3 class, were also large individuals in relation to past populations. As a whole, individuals in the 4_2 class were about average. The small 6_3 group was, however, composed of large individuals, especially amongst the males. Tables VIII to XI summarize the data on the above fish. The 3_2 males (jacks) averaged 15½ inches and 1½ pounds (Tables VIII and IX). The 4_3 age-group, which also consists of jack males, was represented by three fish averaging 15.9 inches in length and 1.7 pounds in weight.

(4) Distribution of Sexes

The over-all percentage of 43 per cent males in the catch more or less reflects the general situation in the Skeena fishery (Table XII). The 38 per cent males in the 5_2

* This figure, taken from the British Columbia catch statistics of the Federal Department of Fisheries, Vancouver, is to the nearest 100 pieces.

fish is partially offset by the 3_2 and 4_3 "jacks" and the slight excess of males in the 5_3 class (Tables VIII and IX).

3. THE RIVERS INLET SOCKEYE RUN OF 1954

(1) General Characteristics

The poor catch of sockeye at Rivers Inlet, 575,700 fish* yielding 50,640 cases, came from the progeny of the 1949 spawning of predominantly 4-year-old fish and the 1950 spawning of predominantly 5-year-old fish. That is, there was a poor spawning of 5-year fish in 1949 and of 4-year fish in 1950, which, if age is inherited, could be expected to result in the poor run which occurred; whether the run actually was poor because of genetical factors for maturity being inherited or because of adverse factors in the environment or because of poor spawn deposition cannot be proven. This is a problem which must eventually be solved before prediction can be put on a firmer basis. In any case, the pack was only half of the average of 100,399 cases for the previous five-year period and not a great deal better in comparison with the average of 87,965 cases for the previous ten years. The escapement was moderate in this area.

(2) Age-groups

The 1954 catch sample was largely 4_2 fish, these comprising 60 per cent of the catch (Table XIII). The remainder was almost wholly 5_2 fish, which formed 39 per cent of the sample. A few 5_3 sockeye were in the sample, and isolated representatives of the 4_1, 3_2, and 6_3 age-groups were also present (Tables XIV and XV).

(3) Lengths and Weights

The 4_2 age-group of the Rivers Inlet catch was comprised of the largest fish recorded for this group in many years (Tables XIV to XVII). Only the average length of the females failed to exceed the records of length and weight compiled since 1942. The 5_2 fish, however, did not set any length records but exceeded recent weight records for the males and equalled them for the females (Tables XVI and XVII).

(4) Distribution of Sexes

In the main age-class, 4_2 fish, the males outnumbered the female sockeye. In the 5_2 age-class the situation was reversed, the males forming only 29 per cent of the sample of this group. For the whole sample the males comprised 52 per cent of the fish. A situation of this type raises the question as to whether some of these 4-year-old males could be "jacks" or precocious males of a population which normally matured at 5 years of age.

4. THE SMITH INLET SOCKEYE RUN OF 1954

(1) General Characteristics

As usual the Smith Inlet sockeye-catch sample was comprised mainly of 4_2 and 5_2 age-group fish. The catch consisted of 190,800 fish* which yielded 18,937 cases of salmon. This is very much below the average of 24,963 cases for the previous ten years, and even poorer when compared to the average of 33,936 cases during the five years immediately preceding this run. There was a heavy escapement of predominantly small-size fish.

(2) Age-groups

The 4_2 age-group formed 61 per cent of the Smith Inlet sockeye-catch sample, with most of the remainder, 38 per cent, being from the 5_2 age-group (Table XIX). Minor numbers of 4_1, 5_3, and 6_3 age-groups were also present (Tables XX and XXI).

* This figure, taken from the British Columbia catch statistics of the Federal Department of Fisheries, Vancouver, is to the nearest 100 pieces.

(3) Lengths and Weights

As may be seen from Tables XXII and XXIII, most of the Smith Inlet sockeye fell within past records for length and weight since the number of fish present in the minor age-classes was very small (Tables XX and XXI).

(4) Distribution of Sexes

Though the Smith Inlet sockeye population was not, on the whole, far from an even sex ratio, 52 males to 48 females, the individual age-groups showed the striking diversions from this ratio which are characteristic of this population. The fact that the 4_2 fish in this group are almost invariably mostly males and the 5_2 fish predominantly females (Table XXIV) seems to point to some degree of linkage between sex and age in this population.

Table I.—Nass River Sockeyes, Percentages of Principal Age-groups in Runs of Successive Years and Packs

Year	Pack in Cases	Number of Sockeye[1]	Percentage of Individuals			
			4_2	5_2	5_3	6_3
1912	36,037	.....	8	27	63	2
1913	23,574	.....	15	12	71	2
1914	31,327	.....	4	41	45	10
1915	39,349	.....	19	14	59	8
1916	31,411	.....	9	17	66	8
1917	22,188	.....	10	15	71	4
1918	21,816	.....	30	16	45	9
1919	28,259	.....	7	22	65	6
1920	16,740	.....	8	14	72	6
1921	9,364	.....	10	7	75	8
1922	31,277	.....	6	2	91	1
1923	17,821	.....	11	6	77	6
1924	33,590	.....	4	3	91	2
1925	18,945	.....	23	8	67	2
1926	15,929	.....	12	12	63	13
1927	12,026	.....	8	7	81	4
1928	5,540	.....	30	6	61	3
1929	16,077	.....	25	9	60	6
1930	26,405	.....	28	15	54	3
1931	16,929	.....	10	17	67	6
1932	14,154	.....	28	4	61	7
1933	9,757	.....	35	7	55	3
1934	36,242	.....	13	9	74	4
1935	12,712	.....	11	10	73	6
1936	28,562	.....	16	7	67	10
1937	17,567	.....	22	4	68	6
1938	21,462	.....	21	4	70	5
1939	24,357	.....	14	13	66	7
1940	13,809	.....	23	8	59	10
1941	24,876	.....	37	7	52	4
1942	21,085	.....	22	7	66	5
1943	13,412	.....	5	13	67	15
1944	13,083	.....	15	15	32	38
1945	9,899	.....	46	11	37	6
1946	12,511	.....	13	12	72	3
1947	10,849	.....	15	12	56	17
1948	13,181	.....	12	16	60	12
1949	9,268	.....	39	6	48	7
1950	27,286	.....	3	19	71	6
1951	24,405	.....	41	9	31	13
1952	29,492	304,500	28	19	46	4
1953	18,163	198,400	23	22	46	9
1954	10,285	101,600	35	20	40	5

[1] To nearest hundred.

Table II.—Nass River Sockeyes, 1954, Grouped by Age, Sex, Length, and by Their Early History

Length in Inches	Number of Individuals												Total
	4_1		4_2		5_2		4_3		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
15													
15¼													
15½							1						1
15¾													
16													
16¼													
16½													
16¾													
17													
17¼													
17½													
17¾													
18													
18¼													
18½													
18¾													
19													
19¼													
19½			1										1
19¾													
20			1						1				2
20¼													
20½									1				1
20¾				2									2
21			1	2									3
21¼				1					1	1			3
21½			1	1						2			4
21¾				8		1			2				11
22				11					1	5			17
22¼			3	12					1	2			18
22½				15					1	5			21
22¾			4	8		1			1	4			18
23			9	19					3	4			35
23¼			5	10		1				8			24
23½		1	11	10		1			1	13			37
23¾			3	11					1	5			20
24			16	9	1	1			13	9		2	51
24¼			4	5	1	2			2	6			20
24½			5	7	2	9			9	9		1	42
24¾			10	2	1	3			3	10		2	31
25			12	3	3	14			13	23		1	69
25¼			1	1		6			7	10			25
25½			5	1	4	11			5	7	1	3	37
25¾			1	1	1	4			4	4			15
26			7		12	10			14	17	1	2	63
26¼			1		3	4			3	3		1	15
26½					2	3			11	4	1		21
26¾					4	3			6	1			14
27					8	1			8	2	1		20
27¼					8				3			1	12
27½					3	1			2			1	7
27¾					2				2		3	1	8
28					3	1			2		2	1	9
28¼					1								1
28½					1						2		3
28¾											1		1
29											2	1	3
29¼													
29½					1								1
Totals		1	101	139	61	77	1		121	154	14	17	686
Average lengths		23.5	24.1	23.1	26.5	25.3	15.5		25.3	24.5	27.7	26.0	24.6

Table III.—Nass River Sockeyes, 1954, Grouped by Age, Sex, Weight, and by Their Early History

Weight in Pounds	Number of Individuals												Total
	4_1		4_2		5_2		4_3		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
1.6							1						1
1.8													
2.0													
2.2													
2.4													
2.6													
2.8													
3.0													
3.2			1										1
3.4			1	1					1				3
3.6									1				1
3.8													
4.0				2									2
4.2			1	3						2			6
4.4				4					2				6
4.6			2	9					1	1			13
4.8			1	10					1	4			16
5.0		1	4	14		1			3	9			32
5.2			1	9	1	1			1	9			22
5.4			5	21					1	6			33
5.6			6	14					3	8			31
5.8			8	12		4			5	8			37
6.0			9	13		2			4	12		1	41
6.2			6	4	1	3				13		1	28
6.4			10	5		3			4	15		1	38
6.6			6	12		4			6	10			38
6.8			5	2	3	3			4	10		1	28
7.0			8	1		6			13	12		2	42
7.2			5	2	1	7			7	10		2	34
7.4			3	1	1	8			3	8			24
7.6			6		2	9			8	8			33
7.8			4		1	5			5	4			19
8.0			4		10	5			5	1		1	26
8.2			2		1	1			12	3		1	20
8.4			2		4	3			7	1	2		19
8.6					4	4			2		1	3	14
8.8					4	1			2		1	2	10
9.0					4	2			7		1		14
9.2			1		2	1			3				7
9.4									3		3		6
9.6					3	1			3				7
9.8					8	1			2				11
10.0					3				2		2	2	9
10.2					3	1					3		7
10.4													
10.6					1	1							2
10.8					2						1		3
11.0					1								1
11.2													
11.4													
11.6													
11.8													
12.0													
12.2					1								1
12.4													
12.6													
Totals		1	101	139	61	77	1		121	154	14	17	686
Average weights		5.0	6.4	5.5	8.8	7.4	1.6		7.4	6.3	9.5	7.8	6.8

Table IV.—Nass River Sockeyes, Average Lengths in Inches of Principal Age-groups, 1912 to 1954

Year	4_2		5_2		5_3		6_3	
	M.	F.	M.	F.	M.	F.	M.	F.
1912–41	24.5	23.7	26.3	25.2	26.1	25.3	27.7	26.4
1912–41 (conversion)	23.8	23.0	25.6	24.5	25.4	24.6	27.0	25.7
1942	23.9	23.2	26.1	24.9	24.9	24.3	26.9	26.0
1943	22.8	22.2	26.1	24.8	24.1	23.5	27.1	25.8
1944	23.5	22.7	25.7	24.6	24.8	23.8	26.8	25.8
1945	23.4	22.8	25.0	24.4	24.7	24.0	25.1	25.5
1946	23.4	22.4	26.3	24.9	24.9	23.9	28.1	26.0
1947	23.4	22.9	25.9	24.1	24.5	23.6	27.0	25.6
1948	23.3	22.6	26.2	25.3	25.0	24.1	27.7	26.7
1949	23.8	22.8	26.2	23.8	24.7	23.7	26.1	25.5
1950	23.6	23.1	26.0	24.7	24.5	23.7	26.7	25.6
1951	24.0	23.1	26.2	24.8	25.1	24.1	27.4	26.4
1952	23.9	23.1	26.8	25.3	24.8	23.9	27.6	26.3
1953	23.9	22.9	26.9	25.6	24.9	24.1	27.7	26.5
1954	24.1	23.1	26.5	25.3	25.3	24.5	27.7	26.0

Table V.—Nass River Sockeyes, Average Weights in Pounds of Principal Age-groups, 1914 to 1954

Year	4_2		5_2		5_3		6_3	
	M.	F.	M.	F.	M.	F.	M.	F.
1914–41	6.0	5.4	7.3	6.4	6.9	6.2	8.0	7.0
1942	5.8	5.1	7.1	6.3	6.2	5.6	7.5	6.7
1943	5.2	4.7	7.6	6.4	5.9	5.3	7.9	6.9
1944	5.7	5.0	7.7	6.5	6.7	5.7	8.2	7.1
1945	5.7	5.3	7.0	6.4	6.5	5.9	7.2	7.1
1946	5.6	4.9	8.1	6.7	6.5	5.4	8.9	7.0
1947	5.8	5.3	7.7	6.2	6.3	5.6	8.1	6.9
1948	5.8	5.3	8.1	7.1	7.0	6.0	9.1	7.9
1949	5.9	5.1	7.9	5.8	6.5	5.4	7.7	6.8
1950	5.9	5.2	7.9	6.6	6.4	5.5	8.2	7.1
1951	6.0	5.2	7.9	6.6	6.7	5.7	8.8	7.6
1952	6.0	5.2	8.4	6.9	6.7	5.7	8.7	7.5
1953	6.2	5.4	8.3	7.2	6.6	5.8	9.0	7.9
1954	6.4	5.5	8.8	7.4	7.4	6.3	9.5	7.8

Table VI.—Nass River Sockeyes, Percentages of Males and Females, 1915 to 1954

Year	4_2		5_2		5_3		6_3		Per Cent Total Males	Per Cent Total Females
	M.	F.	M.	F.	M.	F.	M.	F.		
1915–41 (average)	49	51	47	53	45	55	63	37	47	53
1942	42	58	48	52	44	56	70	30	45	55
1943	51	49	67	33	47	53	74	26	54	46
1944	53	47	45	55	39	61	60	40	50	50
1945	37	63	37	63	38	62	53	47	38	62
1946	62	38	59	41	45	55	75	25	50	50
1947	50	50	52	48	51	49	81	19	56	44
1948	45	55	54	46	52	48	66	34	53	47
1949	57	43	56	44	51	49	50	50	53	47
1950	41	59	42	58	43	57	58	42	44	56
1951	46	54	47	53	46	54	70	30	49	51
1952	49	51	56	44	49	51	59	41	50	50
1953	50	50	44	56	46	54	62	38	48	52
1954	42	58	44	56	44	56	45	55	43	57

Table VII.—Skeena River Sockeyes, Percentages of Age-groups in Runs of Successive Years and Packs

Year	Pack in Cases	Number of Sockeye[1]	Percentage of Individuals			
			4_2	5_2	5_3	6_3
1907	108,413	———	—	—	—	—
1908	139,846	———	—	—	—	—
1909	87,901	———	—	—	—	—
1910	187,246	———	—	—	—	—
1911	131,066	———	—	—	—	—
1912	92,498	———	57	43	—	—
1913	52,927	———	50	50	—	—
1914	130,166	———	25	75	—	—
1915	116,553	———	36	64	—	—
1916	60,923	———	34	38	13	18
1917	65,760	———	57	29	9	5
1918	123,322	———	51	34	9	6
1919	184,945	———	27	60	9	4
1920	90,869	———	15	71	6	8
1921	41,018	———	69	22	6	3
1922	96,277	———	70	16	12	2
1923	131,731	———	56	29	8	7
1924	144,747	———	23	69	7	1
1925	77,784	———	51	45	3	1
1926	82,360	———	62	26	9	3
1927	83,996	———	62	28	9	1
1928	34,559	———	51	39	7	3
1929	78,017	———	62	30	6	2
1930	132,372	———	39	52	8	1
1931	93,023	———	40	30	28	2
1932	59,916	———	44	37	7	12
1933	30,506	———	57	36	5	2
1934	54,558	———	58	34	7	1
1935	52,879	———	49	31	18	2
1936	81,973	———	67	20	11	2
1937	42,491	———	45	40	11	4
1938	47,257	———	64	15	16	5
1939	68,485	———	50	35	11	4
1940	116,507	———	80	15	4	1
1941	81,767	———	39	52	8	1
1942	34,544	———	36	54	7	3
1943	28,268	———	39	39	16	6
1944	68,197	———	37	52	7	4
1945	104,279	———	20	63	12	5
1946	52,928	———	13	70	8	9
1947	32,534	———	14	82	3	1
1948	101,267	———	80	13	6	1
1949	65,937	———	17	76	4	3
1950	47,479	———	21	72	4	3
1951	61,694	———	33	61	4	1
1952	114,775	1,294,500	66	26	3	5
1953	65,003	659,200	48	43	6	3
1954	60,817	571,900	33	54	10	2

[1] To nearest hundred.

Table VIII.—Skeena River Sockeyes, 1954, Grouped by Age, Sex, Length, and by Their Early History

Length in Inches	Number of Individuals												Total
	3_2		4_2		5_2		4_3		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
14													
14¼													
14½	1												1
14¾	3												3
15	1						1						2
15¼	2												2
15½	1												1
15¾	1												1
16													
16¼	1						1						2
16½							1						1
16¾	1												1
17	1												1
17¼													
17½													
17¾													
18													
18¼			1										1
18½													
18¾													
19			2										2
19¼			1										1
19½			1										1
19¾			2	1									3
20			8	2					1				11
20¼			12	2									14
20½			19	1						1			21
20¾			5	7						1			13
21			24	8					1	2			35
21¼			8	5					1				14
21½			9	20	1				2	3			35
21¾			11	23						4			38
22			10	43		2			4	8			67
22¼			5	29					1	5			40
22½			8	44		1			3	8			64
22¾			8	25		2			5	3			43
23			27	36	1	5			3	11		1	84
23¼			6	12		3			3	3			27
23½			18	14	1	16			6	5		2	62
23¾			5	12		7			7	3		1	35
24			17	7	2	46			12	4	1	3	92
24¼			4	1		26			4	1			36
24½			6	1	4	42			6	2	1	4	66
24¾			3	1	6	39			6		1		56
25			7		12	84			5		1	2	111
25¼			3		3	36			2	2	1		47
25½					14	42			2				58
25¾					8	41			3			1	53
26			1		47	67			1		1	3	120
26¼			1		20	18				1	1		41
26½					36	16			1		1	2	56
26¾					30	12			2	1	2		47
27					44	19			1		2		66
27¼					29	3			1		1		34
27½					28	1					1		31
27¾					10						1		11
28					20	1					2		23
28¼					4	1							5
28½					6								6
28¾					2								2
29					2								2
29¼					1								1
Totals	12		232	294	331	530	3		83	68	17	20	1,590
Average lengths	15.5		22.2	22.4	26.6	25.2	15.9		23.9	22.9	26.4	24.9	24.3

Table IX.—Skeena River Sockeyes, 1954, Grouped by Age, Sex, Weight, and by Their Early History

Weight in Pounds	Number of Individuals												Total
	3_2		4_2		5_2		4_3		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
1.0	1												1
1.2	1												1
1.4	2												2
1.6	5						1						6
1.8	1						2						3
2.0	2												2
2.2													
2.4			1										1
2.6			1										1
2.8			1										1
3.0			2										2
3.2			5	2					2				9
3.4			8	3									11
3.6			13	7						1			21
3.8			19	1						2			22
4.0			18	15					1	2			36
4.2			9	13					2	6			30
4.4			13	27	1				2	5			48
4.6			13	36		2			3	3			57
4.8			15	45		1			2	6			69
5.0			16	42		3			2	9		1	73
5.2			10	26		6			1	6			49
5.4			13	29	1	14			3	9		1	70
5.6			16	16		13			5	7			57
5.8			6	15	1	17			11	2		1	53
6.0			17	10	1	36			8	2	1	3	78
6.2			6	4	1	30			6	1		2	50
6.4			5		3	25			5	1		1	40
6.6			7		1	33			3	2	1		47
6.8			5	2	3	34			6			2	52
7.0			3	1	15	41			5	1	1		67
7.2			1		5	38			2	1		1	48
7.4			3		11	45			4				63
7.6			2		9	22			1	1			35
7.8			1		10	31			3		1	2	48
8.0			2		18	39			2	1	2	1	65
8.2					18	22							40
8.4			1		20	8			2		2		33
8.6					27	17					1		45
8.8					21	18						1	40
9.0					25	15					1	2	43
9.2					20	6			1		1	1	29
9.4					21	6					1		28
9.6					15				1		2		18
9.8					22	4					1		27
10.0					25	2							27
10.2					10								10
10.4					4	2					1	1	8
10.6					7								7
10.8					4								4
11.0					3								3
11.2					1								1
11.4					3								3
11.6					1								1
11.8					2								2
12.0					1						1		2
12.2					1								1
Totals	12		232	294	331	530	3		83	68	17	20	1,590
Average weights	1.5		4.9	4.9	8.8	7.2	1.7		6.2	5.2	8.6	7.2	6.6

Table X.—Skeena River Sockeyes, Average Lengths in Inches of Principal Age-groups, 1912 to 1954

Year	4_2		5_2		5_3		6_3	
	M.	F.	M.	F.	M.	F.	M.	F.
1912–41	23.7	23.1	25.8	24.9	24.2	23.4	25.8	24.8
1912–41 (conversion)	23.0	22.4	25.1	24.2	23.5	22.7	25.1	24.1
1942	22.6	22.3	25.2	24.3	24.1	23.7	26.3	24.9
1943	21.9	21.9	25.1	23.9	23.3	22.6	25.8	24.7
1944	22.4	21.7	24.8	23.9	22.5	21.7	25.0	23.7
1945	22.6	22.3	24.9	24.1	23.3	22.6	25.0	24.3
1946	22.7	22.0	25.4	24.3	23.9	23.2	25.5	24.4
1947	22.3	22.0	25.1	23.8	23.0	22.4	26.3	25.8
1948	23.0	22.3	25.3	24.1	23.0	22.1	26.0	24.5
1949	22.5	22.2	25.3	24.5	23.2	22.3	24.8	23.9
1950	22.8	22.3	25.7	24.4	23.9	23.4	25.5	24.3
1951	22.7	22.6	25.9	24.8	23.6	22.9	26.0	24.6
1952	23.3	22.6	25.8	24.7	23.2	22.8	26.1	24.6
1953	23.2	22.8	26.2	25.0	23.6	22.9	26.0	25.5
1954	22.2	22.4	26.6	25.2	23.9	22.9	26.4	24.9

Table XI.—Skeena River Sockeyes, Average Weights in Pounds of Principal Age-groups, 1914 to 1954

Year	4_2		5_2		5_3		6_3	
	M.	F.	M.	F.	M.	F.	M.	F.
1914–41	5.4	5.0	6.8	6.1	5.7	5.1	6.8	6.0
1942	4.9	4.7	6.7	6.0	5.8	5.4	7.2	6.6
1943	4.7	4.6	6.8	5.9	5.5	4.9	7.3	6.1
1944	5.1	4.6	7.0	6.1	5.3	4.6	7.1	5.8
1945	5.2	4.9	6.7	6.1	5.6	5.0	6.7	6.2
1946	4.7	4.2	6.9	5.8	5.8	5.1	7.0	6.1
1947	4.9	4.7	6.9	5.9	5.3	5.0	7.7	6.8
1948	5.5	4.9	7.3	6.1	5.4	4.7	7.7	6.4
1949	5.0	4.7	7.1	6.3	5.3	4.8	6.6	5.7
1950	4.8	4.3	7.2	5.9	5.8	5.1	6.8	5.6
1951	5.1	5.0	7.6	6.5	5.6	5.0	7.6	6.4
1952	5.6	5.0	7.5	6.4	5.6	5.0	7.4	6.0
1953	5.8	5.5	8.0	6.9	5.8	5.2	7.8	7.3
1954	4.9	4.9	8.8	7.2	6.2	5.2	8.6	7.2

Table XII.—Skeena River Sockeyes, Percentages of Males and Females, 1915 to 1954

Year	4_2		5_2		Per Cent Total Males	Per Cent Total Females
	M.	F.	M.	F.		
1915–41 (average)	48	52	43	57	46	54
1942	42	58	25	75	33	67
1943	50	50	31	69	43	57
1944	54	46	34	66	43	57
1945	41	59	35	65	38	62
1946	50	50	32	68	38	62
1947	50	50	29	71	33	67
1948	50	50	29	71	47	53
1949	54	46	30	70	36	64
1950	56	44	40	60	44	56
1951	41	59	37	63	39	61
1952	52	48	34	66	48	52
1953	40	60	34	66	39	61
1954	44	56	38	62	43	57

Table XIII.—Rivers Inlet Sockeyes, Percentages of Age-groups in Runs of Successive Years and Packs

Year	Pack in Cases	Number of Sockeye[1]	Percentage of Individuals			
			4_2	5_2	5_3	6_3
1907	87,874		—	—	—	—
1908	64,652		—	—	—	—
1909	89,027		—	—	—	—
1910	126,921		—	—	—	—
1911	88,763		—	—	—	—
1912	112,884		21	79	—	—
1913	61,745		80	20	—	—
1914	89,890		35	65	—	—
1915	130,350		13	87	—	—
1916	44,936		26	74	—	—
1917	61,195		39	61	—	—
1918	53,401		57	43	—	—
1919	56,258		46	54	—	—
1920	121,254		5	95	—	—
1921	46,300		49	51	—	—
1922	60,700		81	18	1	—
1923	107,174		74	24	2	—
1924	94,891		43	54	2	1
1925	159,554		23	77	—	—
1926	65,581		59	38	2	1
1927	64,461		81	16	3	—
1928	60,044		55	40	4	1
1929	70,260		77	18	3	2
1930	119,170		49	48	2	1
1931	76,428		53	44	2	1
1932	69,732		67	27	5	1
1933	83,507		44	55	1	—
1934	76,923		77	20	2	1
1935	135,038		57	41	1	1
1936	46,351		53	46	1	—
1937	84,832		60	37	3	—
1938	87,942		27	70	1	2
1939	54,143		67	32	1	—
1940	63,469		69	28	3	—
1941	93,378		59	40	1	—
1942	79,199		8	91	—	1
1943	47,602		8	91	—	1
1944	36,852		76	23	1	—
1945	89,735		57	41	2	—
1946	73,320		37	63	—	—
1947	140,087		3	97	—	—
1948	37,665		55	44	1	—
1949	39,495		84	14	1	—
1950	142,710		13	87	(2)	—
1951	102,565		38	60	1	1
1952	84,298	938,700	41	58	1	(2)
1953	132,925	1,522,300	73	26	1	(2)
1954	50,640	575,700	60	39	1	(2)

[1] To nearest hundred.
[2] Age-class represented but less than 0.5 per cent.

Table XIV.—Rivers Inlet Sockeyes, 1954, Grouped by Age, Sex, Length, and by Their Early History

Length in Inches	Number of Individuals												Total
	4_1		3_2		4_2		5_2		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
14													
14¼													
14½			1										1
14¾													
15													
15¼													
15½													
15¾													
16													
16¼													
16½													
16¾													
17													
17¼													
17½													
17¾					1								1
18													
18¼													
18½													
18¾													
19					1								1
19¼					1	1							2
19½					6								6
19¾					5								5
20					10	2							12
20¼					16	4			1				21
20½					11	14							25
20¾					15	14							29
21					22	12							34
21¼					22	14							36
21½					19	17							36
21¾					22	10			1				33
22					18	13				1			32
22¼					16	17		2					35
22½					12	15	1	1					29
22¾					22	4		5					31
23					15	6	1	2		1			25
23¼					9	2	2	6					19
23½					19	1	2	6					28
23¾					9		3	15					27
24					9	1	1	9					20
24¼					4	1	1	9	1				16
24½		1			5		3	7					16
24¾					6		4	21					31
25	1				1		3	18					23
25¼					1		2	15		1			19
25½							6	16					22
25¾							3	25					28
26							3	14					17
26¼							7	14					21
26½							4	7					11
26¾							11	6					17
27							6	4					10
27¼							5	2					7
27½							5	1					6
27¾							1				1		2
28							4	1					5
28¼							2						2
28½							1						1
28¾							1						1
29							1						1
Totals	1	1	1		297	148	83	206	3	3	1		744
Average lengths	25.0	24.5	14.5		22.0	21.6	26.1	25.1	22.1	23.4	27.8		23.2

Table XV.—Rivers Inlet Sockeyes, 1954, Grouped by Age, Sex, Weight, and by Their Early History

Weight in Pounds	Number of Individuals												Total
	4_1		3_2		4_2		5_2		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
1.6			1										1
1.8													
2.0													
2.2													
2.4													
2.6													
2.8					1								1
3.0													
3.2													
3.4					1								1
3.6					7	2							9
3.8					14	8							22
4.0					18	8			1				27
4.2					16	18							34
4.4					31	16			1				48
4.6					26	21	1						48
4.8					15	12		2					29
5.0					22	7		2		1			32
5.2					24	15	1	3					43
5.4					12	11		2					25
5.6					14	9		4	1				28
5.8					15	8	1	8					32
6.0					15	8	4	6		1			34
6.2					12	2	1	9					24
6.4					12	2	2	8					24
6.6					15		1	4					20
6.8					7		4	8					19
7.0	1				6	1	2	10					20
7.2		1			2		1	9					13
7.4					5		1	11					17
7.6					2		3	14		1			20
7.8					1		3	13					17
8.0					2		1	12					15
8.2					1		2	13					16
8.4					1		3	12					16
8.6							4	13					17
8.8							3	6					9
9.0							1	9					10
9.2							5	7					12
9.4							2	4					6
9.6							5	4					9
9.8							5	4					9
10.0							3	1					4
10.2							6	4					10
10.4							1	1					2
10.6							1	1					2
10.8							2						2
11.0							1	2					3
11.2							1						1
11.4							4						4
11.6							1						1
11.8							2						2
12.0							2				1		3
12.2							1						1
12.4							1						1
12.6													
12.8							1						1
13.0													
Totals	1	1	1		297	148	83	206	3	3	1		744
Average weights	7.0	7.2	1.6		5.2	4.8	8.9	7.6	4.6	6.1	11.9		6.2

Table XVI.—Rivers Inlet Sockeyes, Average Lengths in Inches of the 4_2 and 5_2 Groups, 1912 to 1954

Year	4_2		5_2	
	M.	F.	M.	F.
1912–41	22.4	22.4	25.4	24.7
1912–41 (conversion)	21.6	21.6	24.6	23.9
1942	21.9	21.3	25.0	23.8
1943	20.5	21.1	24.3	23.7
1944	21.1	21.0	23.5	23.3
1945	20.9	21.2	24.2	23.9
1946	20.6	21.1	25.1	24.1
1947	20.6	20.7	24.0	23.5
1948	21.4	21.3	25.2	24.2
1949	20.9	21.4	23.8	22.8
1950	21.1	20.8	25.2	24.2
1951	21.9	21.9	25.8	24.8
1952	21.5	21.5	26.0	25.0
1953	21.6	21.8	26.5	25.3
1954	22.0	21.6	26.1	25.1

Table XVII.—Rivers Inlet Sockeyes, Average Weights in Pounds of the 4_2 and 5_2 Groups, 1914 to 1954

Year	4_2		5_2	
	M.	F.	M.	F.
1914–41	4.9	4.8	7.0	6.5
1942	5.1	4.6	7.2	6.4
1943	4.1	4.4	6.8	6.3
1944	4.6	4.4	6.2	6.0
1945	4.3	4.4	6.6	6.4
1946	3.9	3.9	7.2	6.2
1947	4.1	3.9	6.4	5.9
1948	4.7	4.6	7.9	7.0
1949	4.4	4.3	5.9	5.9
1950	4.2	3.9	7.5	6.4
1951	5.2	5.0	8.6	7.4
1952	4.9	4.7	8.7	7.4
1953	4.7	4.7	8.8	7.6
1954	5.2	4.8	8.9	7.6

Table XVIII.—Rivers Inlet Sockeyes, Percentages of Males and Females, 1915 to 1954

Year	4_1		4_2		5_2		Per Cent Total Males	Per Cent Total Females
	M.	F.	M.	F.	M.	F.		
1915–41 (average)	...	...	63	37	34	66	50	50
1942	...	...	61	39	35	65	38	62
1943	..	...	62	38	34	66	36	64
1944	...	...	67	33	33	67	59	41
1945	.	...	70	30	39	61	57	43
1946	...	...	79	21	37	63	53	47
1947	..	...	72	28	35	65	36	64
1948	...	...	50	50	38	62	45	55
1949	36	64	70	30	22	78	63	37
1950	50	50	75	25	36	64	41	59
1951	...	...	66	34	30	70	44	56
1952	...	...	58	42	34	66	44	56
1953	.	...	55	45	33	67	49	51
1954	50	50	67	33	29	71	52	48

Table XIX.—Smith Inlet Sockeyes, Percentages of Age-groups in Runs of Successive Years and Packs

Year	Pack in Cases	Number of Sockeye[1]	Percentage of Individuals				
			4_1	4_2	5_2	6_2	5_3
1925	33,764	———	—	—	—	—	—
1926	17,921	———	—	—	—	—	—
1927	22,682	———	—	—	—	—	—
1928	33,442	———	—	—	—	—	—
1929	9,683	———	—	—	—	—	—
1930	32,057	———	—	—	—	—	—
1931	12,867	———	—	—	—	—	—
1932	25,488	———	—	—	—	—	—
1933	37,369	———	—	—	—	—	—
1934	14,607	———	—	—	—	—	—
1935	31,648	———	—	—	—	—	—
1936	12,788	———	—	—	—	—	—
1937	25,258	———	—	—	—	—	—
1938	33,894	———	—	—	—	—	—
1939	17,833	———	—	—	—	—	—
1940	25,947	———	—	—	—	—	—
1941	21,495	———	—	—	—	—	—
1942	15,939	———	—	—	—	—	—
1943	15,010	———	—	—	—	—	—
1944	3,165	———	—	—	—	—	—
1945	15,014	———	—	50	50	—	—
1946	14,318	———	—	11	89	—	—
1947	36,800	———	—	5	95	—	—
1948	10,456	———	—	7	90	3	—
1949	13,189	———	2	92	5	—	(2)
1950	42,435	———	—	17	83	—	(2)
1951	49,473	———	—	22	77	(2)	(2)
1952	34,834	342,200	—	8	91	(2)	1
1953	29,947	367,100	—	89	10	1	(2)
1954	18,937	190,800	1	61	38	—	1

[1] To nearest hundred.
[2] This age-class was represented by less than 0.5 per cent of the number of fish in the sample.

Table XX.—Smith Inlet Sockeyes, 1954, Grouped by Age, Sex, Length, and by Their Early History

Length in Inches	Number of Individuals										Total
	4_1		4_2		5_2		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
19											
19¼											
19½			1								1
19¾			1								1
20			3	3							6
20¼			4	4							8
20½			4	4							8
20¾			2	2							4
21			21	15							36
21¼			16	9							25
21½			21	14							35
21¾			35	20		1					56
22			38	17		1					56
22¼			39	19	1	3					62
22½			37	15							52
22¾			29	9		4		1			43
23			25	7	1	4	1				38
23¼			21	5		7					33
23½			15	1		8		1			25
23¾			8	1	2	5					16
24		1	6	2	2	10					21
24¼			5		4	17		1			27
24½			3	1	1	26			1		32
24¾			4		4	23					27
25		1	1		2	19				1	24
25¼					7	17					24
25½			1		9	25				1	36
25¾					7	25					32
26		1	1		8	12					22
26¼	1				11	10					22
26½					5	5					10
26¾					5	2					7
27					2	3					5
27¼					2	1					3
27½					1						1
27¾											
28					1						1
28¼					1						1
28½					1						1
Totals	1	3	341	148	77	228	1	3	1	2	805
Average lengths	26.3	25.0	22.3	21.9	25.7	24.9	23.0	23.5	24.5	23.3	23.3

Table XXI.—Smith Inlet Sockeyes, 1954, Grouped by Age, Sex, Weight, and by Their Early History

Weight in Pounds	Number of Individuals										Total
	4_1		4_2		5_2		5_3		6_3		
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.	
2.6											
2.8											
3.0				1							1
3.2			1	3							4
3.4			4	5							9
3.6			4	1							5
3.8			6	3	1						10
4.0			9	17							26
4.2			16	16		1					33
4.4			27	18		1					46
4.6			26	14		3					43
4.8			31	12	1	1		1			46
5.0			37	16		4					57
5.2			29	10	1	6					46
5.4			30	10		3					43
5.6			29	7		5		1			42
5.8			21		1	9	1				32
6.0			25	9	3	11					48
6.2			10	3	1	14					28
6.4			11	1	4	17					33
6.6		1	9		1	9			1	1	22
6.8			2	1	4	12					19
7.0		1	2	1	2	26		1		1	34
7.2			7		5	11					23
7.4			1		1	19					21
7.6			2		4	14					20
7.8			1		6	8					15
8.0	1	1			7	12					21
8.2					4	7					11
8.4			1		6	9					16
8.6					8	4					12
8.8					2	9					11
9.0					5	7					12
9.2					1						1
9.4						2					2
9.6					1	3					4
9.8					1	1					2
10.0					2						2
10.2					1						1
10.4											
10.6											
10.8					1						1
11.0											
11.2					2						2
11.4											
11.6											
11.8											
12.0					1						1
12.2											
Totals	1	3	341	148	77	228	1	3	1	2	805
Average weights	8.0	7.1	5.2	4.7	7.9	7.0	5.8	5.8	6.6	6.7	5.9

Table XXII.—Smith Inlet Sockeyes, Average Lengths in Inches of Age-groups, 1945 to 1954

Year	4_1		4_2		5_2		6_2		5_3	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
1945			22.2	22.0	25.1	24.4				
1946			21.3	22.7	24.7	24.0				
1947			23.2	23.4	25.2	24.3				
1948			21.9	21.7	25.0	24.3	26.7	25.0		
1949	25.4	23.5	21.4	21.7	24.6	24.3		25.5		
1950			21.6	21.7	24.8	24.0			20.5	
1951			22.8	22.0	25.6	24.8		25.1	23.4	
1952			21.8	22.4	25.7	24.9		25.1	22.9	23.1
1953		24.3	22.9	22.3	25.9	25.2			22.8	23.3
1954	26.3	25.0	22.3	21.9	25.7	24.9			23.0	23.5

Table XXIII.—Smith Inlet Sockeyes, Average Weights in Pounds of Age-groups, 1945 to 1954

Year	4_1		4_2		5_2		6_2		5_3	
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.
1945			4.9	4.7	7.1	6.5				
1946			4.6	5.8	7.3	6.6				
1947			5.7	5.5	6.9	6.0				
1948			5.1	5.4	7.6	6.9	10.3	7.5		
1949	7.9	6.1	5.0	5.1	7.2	6.7		7.3		
1950			4.9	5.0	7.4	6.6			4.0	
1951			6.0	5.2	8.2	7.3		7.2	6.4	
1952			4.8	5.2	8.0	7.1		7.3	5.7	5.4
1953		5.9	5.9	5.3	8.2	7.6			5.7	5.8
1954	8.0	7.1	5.2	4.7	7.9	7.0			5.8	5.8

Table XXIV.—Smith Inlet Sockeyes, Percentages of Males and Females, 1945 to 1954

Year	4_1		4_2		5_2		6_2		5_3		Per Cent Total Males	Per Cent Total Females
	M.	F.	M.	F.	M.	F.	M.	F.	M.	F.		
1945			73	27	49	51					61	39
1946			76	24	37	63					41	59
1947			38	62	47	53					46	54
1948			79	21	42	58	11	89			43	57
1949	36	64	80	20	40	60		100			77	23
1950			86	14	42	58			100		49	51
1951			72	28	41	59		100	100		48	52
1952			57	43	38	62		100	63	37	40	60
1953		100	60	40	36	64			71	29	58	42
1954	25	75	70	30	25	75			25	75	52	48

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The Status of the Major Herring Stocks in British Columbia in 1954-55

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THE STATUS OF THE MAJOR HERRING STOCKS IN BRITISH COLUMBIA IN 1954–55

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INTRODUCTION

This report presents a review of the present status and level of abundance of the major herring stocks in British Columbia and of the results of the tagging programme obtained in 1954–55.

The past eight reports* in this series have dealt with the results of the comparative study of the herring populations on the west coast and lower east coast of Vancouver Island under different methods of management. In both populations it was found that no direct relationship existed between the amount of spawn deposited and the size of the resulting year-class and that the fluctuations in year-class strength were more readily explained by variations in natural factors affecting survival than by any effect of fishing. It became apparent that further information bearing on the relationship between spawn deposition and resulting year-class strength could be expected only when a series of poor year-classes contributed to the fishery for several years in succession and then, in all probability, only if the fishery were more intense than it had been in the past. In view, therefore, of the indefinite period for which the study would need to be continued, it was thought preferable to terminate the experiment after the 1953–54 season and to substitute at a later date a controlled fishery experiment of a type that would offer better possibilities for obtaining the required results within a more definite period. The proposed experiment would be carried out in an area where fishing intensity could be increased to higher levels than on the west coast of Vancouver Island.

Research on the Pacific herring (*Clupea pallasi*) is carried out at the Pacific Biological Station, Nanaimo, B.C., by the Fisheries Research Board of Canada. In addition to the studies on adult herring, an investigation to determine the relationship between the abundance of juvenile (I-year) herring and year-class strength at recruitment is in progress and will be reported at a later date.

Fig. 1 is a map of British Columbia showing the sub-districts and statistical areas into which the waters of the Province are divided, together with some of the place-names mentioned in the text and tables.

THE 1954–55 FISHERY

The total catch of herring in 1954–55 was 169,163 tons, the lowest since 1946–47.* While catches were good in the Queen Charlotte Islands, the upper east coast of Vancouver Island, the middle east coast of Vancouver Island, and the lower east coast of Vancouver Island sub-districts, they were poor in the northern, the central, and the west coast of Vancouver Island sub-districts. The table below shows for each sub-district the catch and catch per unit of effort in 1954–55 and 1953–54, and the average catch from 1950–51 to 1954–55.

* Previous publications in this series are: Tester and Stevenson, 1947, 1948; Stevenson, 1950; Stevenson and Lanigan, 1950; Stevenson, Hourston, and Lanigan, 1951; Stevenson, Hourston, Jackson, and Outram, 1952; Stevenson and Outram, 1953; Taylor and Outram, 1954.

* With the exception of 1952–53, when there was no major fishery because of a dispute between industry and union.

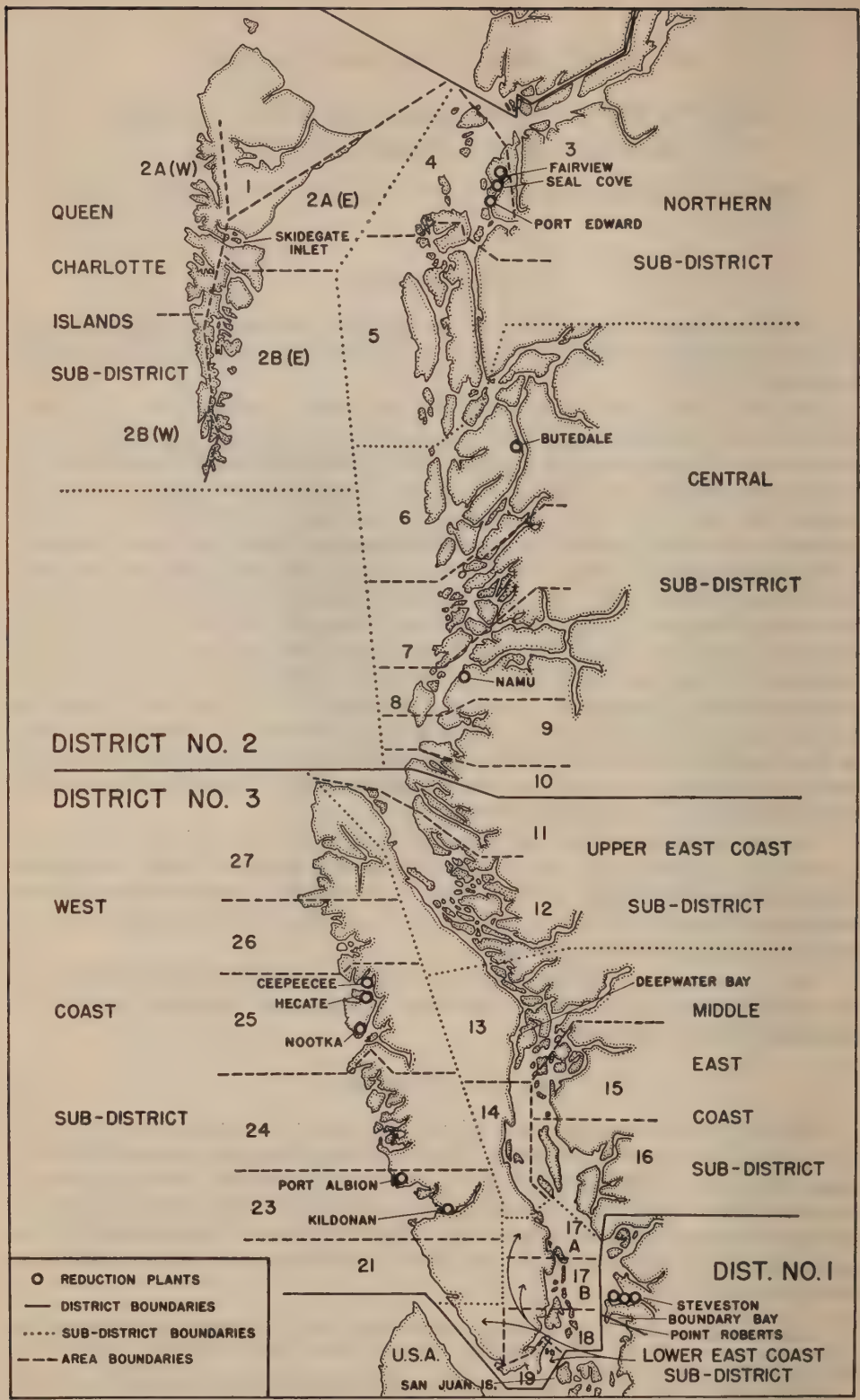

Fig. 1. Map showing the division of the British Columbia coast into districts, sub-districts, and areas.

Sub-district	Catch, 1954–55	Catch, 1953–54	Average Catch, 1950–51 to 1954–55[1]	Catch per Unit of Effort, 1954–55	Catch per Unit of Effort, 1953–54
Queen Charlotte Islands	22,350	28,550	16,312	76	218
Northern	20,050	29,750	39,438	51	77
North Central	9,700	7,500	9,350	22	30
South Central	17,850	24,150	28,250	31	68
Upper east coast of Vancouver Island	9,200	6,650	7,600	82	35
Middle east coast of Vancouver Island	24,650	19,600	16,663	40	49
Lower east coast of Vancouver Island	51,300	52,660	46,502	56	82
South west coast of Vancouver Island	6,863	31,550	17,118	18	53
North west coast of Vancouver Island	7,200	9,800	10,485	61	28
Totals (tons)	169,163	210,210	189,535	—	—

[1] Catches in 1952–53 were omitted.

As in 1953–54, almost the entire Queen Charlotte Islands catch, the second highest on record, came from Skidegate Inlet. Fish were not nearly as abundant as in the previous year, when the entire catch was taken in fourteen fishing-days between February 25th and March 16th. In 1954–55 the season extended from November 30th to February 9th, when it was closed to protect the numbers of small fish present. The catch per unit of effort was a third of that in 1953–54.

In the upper east coast of Vancouver Island sub-district the catch in 1954–55 was the highest since 1940–41. In marked contrast to previous years, Area 11, instead of Area 12, provided the bulk of the catch. In the latter part of November and early December a new fishing-ground in Seymour Inlet and Nugent Sound was exploited and yielded 7,300 tons in a short vigorous fishery. In Area 12, 1,900 tons were taken from Clio Channel, Retreat Pass, McKenzie Sound, and Belle Isle Sound.

Of the record middle east coast of Vancouver Island catch of 24,650 tons, 5,100 tons were taken in early July and in early September in the summer fishery in Area 14; the remainder of the catch came from the winter fishery in Deepwater Bay (Area 13). This fishery also took place in two periods—one in late October and the other in late January. Although only sporadic fishing occurred in the interval, a large body of fish was present in Seymour Narrows, but until late January remained too deep to be fished. Two quota extensions were granted—one for 5,000 tons on November 2nd, taken on January 18th, the other for 10,000 tons on January 23rd, taken on February 3rd. As in 1953–54, the catch per unit of effort in the summer fishery was low, amounting to 33 tons per seine-day. In the winter fishery, catch per unit of effort was higher than in the summer fishery, amounting to 56 tons per seine-day in October and a little over 80 tons per seine-day in January, but was somewhat lower than in 1953–54.

In the lower east coast sub-district, while the catch nearly equalled the record catch of the previous year, catch per unit of effort was somewhat lower. Abundance, however, was still at a high level. The quota was taken in three weeks, with the fishing improving throughout the period. A quota extension of 10,000 tons, granted on November 7th, was taken by November 15th in spite of the hindrance to fishing by exceptionally strong tides in the Swanson Channel region. Sporadic fishing by one or two boats continued until late February under a special quota extension for canning and bait purposes of 5,000 tons.

In the northern sub-district the decrease in abundance noted in 1953–54 continued. Both catch and catch per unit of effort were less than in the previous year, and the quota was not reached for the first time since 1948–49. Although the sub-district was extensively scouted, no fish were found until mid-January, when they appeared in Kitkatlah Inlet and provided two weeks of fishing. No other bodies of fish were located.

In the central sub-district the quota was not reached for the second year in succession. While the catch in the north central region was slightly higher than in the previous year, that in the south central region was lower. The total catch, slightly less than in 1953–54, was the smallest since 1946–47. Catch per unit of effort declined sharply,

particularly in the south central region. The fishery was characterized by a greater dependance than in previous years on local populations. The migratory stocks which usually support the fishery made a comparatively small contribution in 1954–55. Fishing in the central sub-district was closed on February 9th, a month earlier than the regular official closing date, with the provision that it would be reopened if substantial new stocks came on to the fishing-grounds.

In the west coast of Vancouver Island sub-district, the catch declined sharply and was the smallest since 1943–44. In Barkley Sound (Area 23) the catch was the lowest since 1944–45, and catch per unit of effort was reduced to only 18 tons per seine-day. No large bodies of fish were found, and the fishing was dependent on the inshore movement of a succession of small schools. Virtually no fish were caught in Areas 24 and 26, and in Area 25 the fishery was a complete failure for the first time since 1943–44. In contrast to other west coast areas, Area 27 produced a record catch of 6,550 tons in a short vigorous fishery. Catch per unit of effort was 77 tons per seine-day.

TAGGING AND TAG-RECOVERY

Herring have been tagged extensively in British Columbia since 1936. The aims of this programme were (1) to confirm the existence of the discrete populations deduced from meristic and age composition studies (Tester, 1937), (2) to define more precisely the regions occupied by such populations, (3) to assess the extent of movement both between and within populations, and (4) to permit, in certain areas, a rough estimation of the rate of exploitation by the fishery. Detailed analyses of each year's data have appeared in previous Annual Reports of the British Columbia Fisheries Department. Stevenson (1955) reviewed and analysed the results obtained from 1936–37 to 1951–52. The primary objectives of the intensive coastwise tagging programme are now considered to have been achieved. The general relationship between most populations is sufficiently well understood for the practical purposes of management. The annual variation in the extent of intermingling between populations was not considered large enough to warrant the continued expenditure entailed in a coastwise programme. It was decided, therefore, to abandon coastwise tagging, but to continue tagging in specific areas to elucidate the more complex relationships existing there between certain stocks.

Because of the suitability of the stocks in the middle and lower east coast of Vancouver Island sub-districts as subjects for a future controlled fishery experiment and because of the complex relationships existing between herring runs, particularly in the former sub-district, it was decided to confine tagging in 1955 to these stocks. Through the co-operation of the Washington State Department of Fisheries it was hoped to extend the programme to cover populations in contiguous American waters. As the comparative study of the lower east coast and west coast of Vancouver Island populations had been discontinued after the 1953–54 season, no tagging was done in the latter sub-district.

A total of 17,505 tags were put out in the middle east coast and lower east coast sub-districts. American waters in the San Juan Islands-Boundary Bay regions were scouted, but no herring were found. Methods used in tagging herring were the same as employed in previous years (Tester and Stevenson, 1947).

Table I is a list of all taggings made during the 1955 spawning season and includes information on the place and date of each tagging. The numbers of fish tagged in the various areas are shown in the table below:—

Year	Sub-district and Area of Tagging						Total
	Middle East Coast			Lower East Coast			
	13	14	15	17A	17B	18	
1954	____	1,503	1,511	2,015	2,006	4,053	11,088
1955	1,500	2,953	3,020	3,025	5,509	1,498	17,505

Tags were recovered during the 1954–55 season mainly from plant magnets tended by reduction-plant crews. A small number of tags were recovered by tag-detectors operated by investigation personnel.

During the 1954–55 season only one tag-detector was operated, in the Gulf of Georgia plant at Steveston. The percentage efficiency of this induction-type detector was 44 per cent during the pre-Christmas period, as compared to 51 per cent for the same period the previous season and 80 per cent in 1951–52. To prevent interference from a near-by weighing-machine, the detector had to be operated with the sensitivity reduced to a point where it was only partially effective in recovering tags. This would account for its low percentage efficiency.

The installation in the Colonial plant of a new detector using an "Alnico" permanent magnet proved unsuccessful because of electrical interference from plant machinery.

The whole problem of tag-detector construction and operation received close study during the year. The conclusion was reached that the basic fault with the system lay in the fact that the frequency of the impulse produced by a tag lay in the same frequency range (0–10 cycles per second) as variations in line voltage and as switching transients caused by the operation of plant machinery. Because of the small size of the tag, the amplitude of the pulse it produced was little, if any, greater than that produced by such transients. There appear to be three possible solutions to the problem of detector instability:—

(1) An increase in the size of the tag, which may be undesirable on biological grounds.
(2) The use in tags of an alloy with a high nickel content to increase the size of the pulse produced.
(3) The screening of both detector and coil to reduce the effect of the transients.

Further experiments are under way to determine how effective is each of the above methods and which is the most practical.

The efficiency of the various plants in recovering and submitting tags found on the magnets depends on both the mechanical efficiency of the magnets and on the diligence of the plant crews. Magnet efficiency tests were conducted in the same manner as in previous years (Stevenson, Hourston, Jackson, and Outram, 1952). A table of the average 1954–55 efficiency for each plant, with its average efficiency the previous season in parentheses, is given below:—

Plant	Number of Tests	Average Efficiency
West Coast		
Port Albion	1 (1)	92 (90)
Steveston and Vicinity		
Imperial	2 (3)	87 (96)
Gulf of Georgia	3 (2)	94 (97)
Colonial	2 (2)	91 (92)
Phoenix	4 (2)	98 (92)
North Shore	2 (3)	79 (97)
Average		90 (94)
North and Central British Columbia		
Butedale	2 (2)	83 (96)
Port Edward	2 (4)	87 (92)
Seal Cove	3 (1)	64 (68)
Average		78 (85)

Port Albion was the only west coast of Vancouver Island plant to operate in 1954–55. Kildonan and Nootka were ready but never received fish. Ceepeecee was destroyed by fire; Hecate was dismantled. The reduction plant at Namu was enlarged and rebuilt in 1954, the new construction being such that no magnets could be installed in the meal-lines. No efficiency tests were carried out at the new Fairview plant in Prince Rupert. The North Shore plant was remodelled in 1954, and this no doubt explains the 18-per-cent drop in efficiency. The decreased efficiency of Butedale may be explained by the fact that both efficiency tests were carried out just before the plant closed down for a period; some tags could thus have been retained in the plant machinery. The low efficiency of the Seal Cove plant results from use of a cyclone drier and the lack of a magnet in one meal-line carrying 40 per cent of the meal. Only relatively small variations in efficiency occurred in other plants. The tests at plants in north and central British Columbia were carried out by officers of the Department of Fisheries, the remainder by personnel of the Pacific Biological Station.

Recoveries by Tag-detectors

In 1954–55 detector recoveries again showed a marked decrease. A total of 29 tags were recovered—28 from the Gulf of Georgia plant and 1 from the experimental installation in the Colonial plant. Detector recoveries amounted in 1953–54 to 67 and in 1951–52 to 226. The marked reduction in detector recoveries in 1954–55 results from the continuous operation of only one detector, from the continued reduced efficiency of this appartus, and from the smaller number of tags present in the herring stocks. Detector recoveries shown by area of tagging and area of recovery are shown in Table II. The number of tag-detector recoveries in 1954–55 is too small to permit reliable analyses of movements of herring both between and within populations.

Recovery of Tags by Plant Crews

In 1954–55, 2,289 tags were recovered from magnets and plant machinery in ten reduction plants. This total represents a considerable decrease from the record number of 4,528 tags recovered in 1953–54. The reduction in recoveries was expected, and is accounted for primarily by the sharply reduced tagging carried out in 1954 as compared to previous years (*see* table on page 61, Taylor and Outram, 1954) and to a lesser extent by the smaller total catch in 1954–55.

The distribution of tags by area of tagging and probable sub-district of recovery is shown in Table III.

The limitations on the accuracy of the use of plant magnet recoveries in assessing the movement of fish between populations have been discussed in previous reports (Taylor and Outram, 1954, and preceding reports). The same methods as employed in previous years (Tester and Stevenson, 1948) have been used to assign the most probable area of recovery to each plant magnet return. Table III shows that for 545 tags or 23.8 per cent the most probable area of recovery could not be readily determined. This is double the 10.7 per cent obtained in 1953–54. The increased number of tags doubtful as to area of recovery is probably accounted for by plants processing a greater proportion of fish from different areas at the same time than in previous years. Because of the very small number of detector recoveries, the analysis of the movements of herring between populations has been based on the probable number of tags in the catches derived from plant magnet returns. Due to the uncertainty as to the exact area of recovery of magnet returns, analyses of movement within populations were not possible. The probable numbers of tags were calculated in the same manner as in 1953–54 (Taylor and Outram, 1954). They are shown in Table IV, together with the actual numbers on which the calculations are based. Table IV is summarized in the tabulation below, which shows the probable number of tags in the catches by sub-district of tagging and probable sub-district of recovery; actual numbers of recoveries are given in parentheses.

Sub-district of Tagging	Sub-district of Recovery									Total
	Queen Charlotte Islands	Northern	North Central	South Central	Upper East Coast	Middle East Coast	Lower East Coast	South West Coast	North West Coast	
Queen Charlotte Islands	984	66	———	———	———	2	———	———	———	1,052
	(729)	(45)	———	———	———	(2)	———	———	———	(776)
Northern	25	850	9	4	———	1	———	———	———	889
	(15)	(557)	(7)	(2)	———	(1)	———	———	———	(582)
North central	———	26	33	35	———	———	———	———	———	94
	———	(17)	(29)	(17)	———	———	———	———	———	(63)
South central	2	3	20	276	———	19	———	1	8	329
	(2)	(3)	(18)	(120)	———	(18)	———	(1)	(6)	(168)
Upper east coast	———	———	———	———	14	22	———	———	4	40
	———	———	———	———	(12)	(21)	———	———	(3)	(36)
Middle east coast	———	2	1	———	———	146	3	———	———	152
	———	(2)	(1)	———	———	(138)	(3)	———	———	(144)
Lower east coast	———	———	———	2	———	60	229	2	1	294
	———	———	———	(1)	———	(58)	(191)	(2)	(1)	(253)
South west coast	———	———	2	2	———	6	13	32	10	65
	———	———	(2)	(1)	———	(6)	(13)	(31)	(9)	(62)
North west coast	———	2	———	———	1	2	9	2	71	87
	———	(2)	———	———	(1)	(2)	(9)	(2)	(56)	(72)
Totals	1,011	949	65	319	15	258	254	37	94	3,002[1]
	(746)	(626)	(57)	(141)	(13)	(246)	(216)	(36)	(75)	(2,156)

[1] Tags recovered at the Fairview plant, where no magnet efficiency tests were carried out, were omitted in the calculations of the probable numbers of tags.

As in previous years, most of the recoveries were made from the same sub-district in which the fish were tagged. Although unknown differences in the exploitation of the populations in the various sub-districts prevent any comparisons of the relative strength of the "homing tendency," this tendency would appear to be strongest in 1954–55 in the Queen Charlotte Islands, the northern, and the middle east coast of Vancouver Island sub-districts, and weakest in the south west coast of Vancouver Island, the north central, and the upper east coast of Vancouver Island sub-districts.

The dispersion of upper east coast tags indicated by the returns in the table may be greater than the dispersion that actually occurred. Recoveries, with one exception, were from a series of tags put out in Retreat Pass in 1953, and were largely made by one plant late in the season. An examination of the catch records of this plant indicate the possibility that some, at least, of these tags may have come from catches from Knight Inlet (Area 12) rather than from Deepwater Bay (Area 13) in the middle east coast sub-district.

Movement of herring from the west coast of Vancouver Island to other sub-districts was 24 per cent (37/152). This is considerably greater than the corresponding emigrations in previous years (3 per cent in 1953–54, 8 per cent in 1951–52, and 15 per cent in 1950–51). Tagging on the west coast was very light in 1954, and the bulk of the recoveries were from tags put out in 1953. The greater degree of emigration noted may partially be due to the greater opportunity for mixing arising from the majority of the tagged fish having been at liberty for more than a year. The bulk of the movement was to the lower east coast sub-district. Movement to this sub-district was greater from south west coast areas (20 per cent, 13/65) than from north west coast areas (10 per cent, 9/87). The movement of lower east coast herring to the west coast (1 per cent, 3/294) was considerably lower than in previous years (13.5 per cent in 1953–54, 7.5 per cent in 1951–52, and 10.5 per cent in 1950–51). The disparity in the movements in the two directions between the west coast and lower east coast sub-districts is the reverse of that noted in 1953–54 (Taylor and Outram, 1954), when 13.5 per cent of lower east coast herring moved to the west coast and 2.9 per cent of west coast herring moved to the lower east coast. Movement of herring from the south west coast of Vancouver Island to the north west coast was 15 per cent (10/65), whereas movement in the reverse direction was only 2 per cent (2/87).

In 1954–55 the dispersion of middle east coast tags was considerably less than in previous years, only approximately 4 per cent (6/152) migrating to other areas, compared to an average of 45.5 per cent (Stevenson, 1955). Approximately 2 per cent (3/152) of the middle east coast tags were recovered from the lower east coast, compared to 17 per cent in 1953–54 and to 6.8 per cent from magnet recoveries or to 29.9 per cent from detector recoveries in 1951–52. Movement of lower east coast fish to the middle east coast was 20 per cent (60/294), a little greater than the 16 per cent found in 1953–54. This is the reverse of the situation found by Stevenson (1955) from an analysis of tag returns from 1936–37 to 1951–52. He found that movement in the southerly direction greatly exceeded that in the northerly (27.6 per cent as compared to 6.7 per cent). The movement to the middle east coast of fish tagged in Area 17A (46 per cent) was greater than for those fish tagged in Area 17B (14 per cent) or Area 18 (6 per cent). Of fish tagged in Area 17A, more recoveries were from Area 14 of the middle east coast sub-district than from Area 13. A series of tags put out at Schooner Cove (Area 17A) in the northern part of the lower east coast sub-district in March, 1954, showed an interesting pattern of recoveries illustrating the complex type of intermingling that may occur between the lower east coast and middle east coast stocks. Of 70 tags recovered from this series, 57 could be assigned to a definite area. Of these 57, 16 were recovered from the middle east coast summer fishery (Area 14), 30 from the winter fishery in the lower east coast sub-district, and 11 from the middle east coast late winter fishery (Area 13). While several explanations are possible, the most probable seems to be that some of these fish joined the stock that remained throughout the summer in the middle east coast sub-district, others joined the middle east coast stock that migrated to offshore feeding-grounds and returned by way of Johnstone Strait, while others, possibly the largest portion, joined the main lower east coast stocks which moved offshore and returned by way of the Strait of Juan de Fuca.

The main movement of fish from the south central sub-district was to the north central (6 per cent, 20/329) and to the middle east coast (6 per cent, 19/329) sub-districts. Recoveries from herring tagged in the north central sub-district suggest that approximately the same proportion of fish migrated to both the northern (28 per cent, 26/94) and south central (37 per cent, 35/94) sub-districts as remained within the sub-district of tagging (35 per cent, 33/94). The main movement of fish from the northern sub-district was to the Queen Charlotte Islands (3 per cent, 25/889) and to the north central (1 per cent, 9/889) sub-districts, approximately the same as in 1953–54. Herring were tagged in Skidegate Inlet (Area 2A-E) in the Queen Charlotte Islands for the first time in 1954. The main movement (3.4 per cent, 34/1,009) of these fish was to the northern sub-district (Table IV). Only three fish tagged in Area 2B-E were recovered in the Skidegate Inlet fishery. This suggests that there are probably separate stocks in the two Queen Charlotte Islands areas. Of fish tagged in Area 2B-E, 74 per cent (32/43) of the recoveries were from the northern sub-district and only 21 per cent (9/43) from the Queen Charlotte Islands sub-district (Table IV). However, because of the very small fishery (550 tons) in Area 2B-E it is unlikely that the returns this year represent a true picture of the dispersion from this area.

AGE COMPOSITION

The average percentage age composition of the herring from each major population for the past two seasons are given below. The data are weighted according to the numbers of fish caught in each statistical area.

Sub-district or Population	In Year of Age								
	I	II	III	IV	V	VI	VII	VIII	IX and Over
Queen Charlotte Islands—									
1953–54	0.04	2.42	27.19	21.28	*35.11*	10.66	2.33	0.68	0.29
1954–55	——	7.82	13.77	*40.89*	18.06	14.80	4.18	0.29	0.19
Northern—									
1953–54	——	0.82	24.30	*31.48*	26.31	14.17	2.30	0.58	0.05
1954–55	——	2.78	4.90	*70.79*	15.32	5.02	1.04	0.15	——
North central—									
1953–54	0.42	5.12	*74.48*	14.11	4.93	0.94	——	——	——
1954–55	0.54	12.43	18.73	*63.12*	4.06	0.87	0.21	——	——
South central—									
1953–54	0.12	4.16	*69.79*	19.82	4.58	1.34	0.14	——	0.05
1954–55	0.38	6.10	10.24	*68.19*	12.03	2.62	0.44	——	——
Upper east coast—									
1953–54	0.14	9.30	*65.89*	15.20	6.61	2.33	0.44	0.08	——
1954–55	0.15	5.79	31.77	*48.05*	11.61	2.07	0.41	0.14	——
Middle east coast—									
1953–54	——	2.64	30.31	*42.13*	16.56	6.29	1.67	0.35	0.04
1954–55	——	5.87	36.40	*43.86*	7.70	6.10	0.08	——	——
Lower east coast—									
1953–54	——	0.72	*58.03*	34.36	6.06	0.62	0.14	0.04	0.02
1954–55	——	2.79	*57.44*	33.24	5.79	0.49	0.07	——	——
South west coast—									
1953–54	0.09	2.71	*64.29*	26.64	5.44	0.58	1.14	0.07	0.03
1954–55	0.03	16.82	*59.40*	19.81	3.32	0.60	0.03	——	——
North west coast—									
1953–54	——	——	*44.91*	42.13	9.56	2.32	1.08	——	——
1954–55	——	6.36	34.82	*50.04*	6.96	1.48	0.27	0.06	——

In 1954–55 the 1951 year-class, as IV-year fish, was the major contributor to the herring runs in all but the lower east coast of Vancouver Island and south west coast of Vancouver Island populations. In these latter populations the 1952 year-class (III-year fish) was dominant. In spite of the large percentages of IV-year fish in the catches, the 1951 year-class is considered to be of no more than average strength in the northern and the north and south central populations in view of the decreased catches and only average spawnings of the past two seasons. The 1951 year-class was somewhat stronger than the 1950 year-class. In the upper, middle, and lower east coast of Vancouver Island populations the 1951 year-class was of above-average strength. In the west coast of Vancouver Island population this year-class was of average strength, and was somewhat stronger in the south west coast areas and Quatsino Sound than in the remaining areas.

In all populations the 1952 year-class (III-year fish) appears to be weaker than the 1951 year-class. In the Queen Charlotte Islands, northern, and north and south central populations it made the smallest contributions for III-year fish for a number of years. In these populations it must be considered a weak year-class. In the middle and lower east coast and in the south west coast of Vancouver Island populations this year-class made an average contribution for III-year fish for recent years. In the latter two populations it was the dominant age-class. This year-class is probably of above-average strength in the middle and lower east coast of Vancouver Island populations. In the west coast of Vancouver Island populations it is of below-average strength, and is weaker in the north west coast than in the south west coast populations.

The percentage of II-year fish (the 1953 year-class) in the catches in 1954–55 was higher than in the previous season in all except the upper east coast population. The largest contributions were in the north central and south west coast populations. In the south central population, although the percentage of II-year fish in the local stocks was higher than in the previous season, in the main offshore or migratory stocks it was lower.

While the greater contribution of II-year fish in 1954–55 suggests that the 1953 year-class may be stronger than the 1952 year-class, in most populations the contributions were not sufficiently outstanding, considering the relative weakness of the older year-classes, to suggest that the 1953 year-class will be of much more than average strength.

In the Queen Charlotte Islands (Skidegate Inlet) population in 1954–55, as in the preceding year, the proportion of older fish of V, VI, and VII years was greater than in other populations. The greater predominance of older fish may be related to the short period (two seasons) of exploitation. If as intense exploitation continues, the numbers of older fish may be reduced in future years and the age composition of the stock come to resemble more closely that of other northern populations.

AVERAGE LENGTH AND WEIGHT

Information on possible changes in environmental factors (food-supply, temperature, etc.) affecting growth is provided by the annual variations in the average length and weight of herring of each age-class. The average weight of the various age-groups in a population, together with its percentage age composition, are also used in the calculation of the numbers of fish in the catch.

The average lengths and weights of herring of Ages II to VI in each of the major populations are given in the table below for 1954–55. Those derived from samples taken in the regular winter fishery are denoted " F." and those from samples taken in the 1955 spawning season by " S." No weights are taken in samples of spawning fish. For comparison, the average lengths and weights for the period 1945–46 to 1954–55 are given in parentheses for all populations except those of the Queen Charlotte Islands and upper east coast of Vancouver Island. The population in Area 2A-E of the Queen Charlotte Islands sub-district has been exploited for the past two seasons only; before this the fishery centred in Area 2B-E. Tag returns have suggested that these two populations are relatively distinct and, as will be discussed later, the growth rates differ noticeably. The fishery in the upper east coast sub-district is dependent upon six or seven local populations, not all of which are fished each season. As the fish in some of these populations are fast growing, in others slow growing, the average lengths and weights in one year are not strictly comparable to those in another.

	Average Length (Mm.)					Average Weight (Gm.)				
	II	III	IV	V	VI	II	III	IV	V	VI
Queen Charlotte Islands (Area 2A-E)—F.	147	163	184	202	214	40	58	86	115	135
Northern—F.	156(146)	182(174)	194(191)	205(199)	218(207)	40(36)	80(68)	92(96)	114(108)	132(120)
North central—F.	146(146)	162(175)	179(189)	194(198)	188(204)	41(38)	64(73)	84(95)	105(110)	97(119)
South central (Areas 7, 8, 9, 10)—F.	133	161	181	195	202	30	60	85	109	124
Area 7—F.	160(154)	177(179)	192(195)	210(205)	218(212)	49(43)	75(76)	98(99)	122(118)	144(133)
Upper east coast—F.	136	159	165	178	208	33	61	67	86	135
Middle east coast—										
F.	150(151)	177(180)	190(198)	205(212)	216(221)	45(44)	80(78)	119(110)	124(134)	145(157)
S.	163	183	196	211	225	——	——	——	——	——
Lower east coast—										
F.	163(156)	188(188)	200(199)	211(212)	225(221)	57(49)	94(90)	113(110)	132(132)	163(150)
S.	156	188	199	212	221	——	——	——	——	——
South west coast—F.	164(162)	182(187)	199(201)	210(212)	222(230)	58(54)	83(87)	108(110)	125(130)	151(140)
North west coast—F.	154(162)	180(188)	195(203)	210(213)	216(222)	46(52)	84(87)	105(109)	135(133)	142(150)

A comparison of the average lengths and weights for the ten-year period 1945–46 to 1954–55 indicates that fish from Northern British Columbia are smaller and lighter at each age than those from Southern British Columbia. The growth rates of fish from the northern and north central populations are very similar, as also are those from the lower east coast and west coast of Vancouver Island. Fish from the south central and middle east coast of Vancouver Island populations are intermediate in average length and weight between the northern and southern groups. These differences would indicate either that feeding conditions are generally better in the south than in the north or, more probably, that other environmental conditions are more favourable for rapid growth in

the south. It is known that southern herring mature earlier than those in the north, and that while in the south recruitment occurs mainly at Age III with a small proportion at Ages II and IV, in the north it occurs mainly at Ages III and IV. It is interesting to note that in the middle east coast population fish of Ages II and III resemble more closely fish from the south central populations, while those of Ages IV to VII resemble those of the lower east coast and west coast of Vancouver Island populations. Tag returns have indicated both that the migration route for adult herring from the middle east coast sub-district is mainly northwards through Johnstone Strait and also that considerable intermixture between the middle and lower east coast stocks takes place, probably within the Strait of Georgia. Very little is known of the migration of herring prior to recruitment. However, it would not seem unreasonable to assume that juvenile herring follow essentially the same migration route as adults. If this is so, it offers a reasonable explanation for the growth pattern in the middle east coast. Prior to recruitment, herring from the middle east coast and south central populations would be subject to essentially similar environmental conditions. After recruitment, not only would herring from the middle and lower east coast populations be subject to similar environmental conditions for at least part of the year, but considerable intermixture between the two stocks could occur. The influx of lower east coast herring into the middle east coast sub-district would tend to decrease the average size of the older fish found there, and conversely the influx of middle east coast herring into the lower east coast sub-district would tend to increase the average size of the older groups in the lower east coast sub-district. Thus, while middle east coast herring of Ages II and III might reasonably be expected to resemble herring from the south central population, it might also be expected that in the older age-groups middle and lower east coast herring would resemble each other.

In 1954–55 the average weights of herring of each age-class in the northern and lower east coast of Vancouver Island populations were slightly greater than the ten-year averages, whereas in the north central and middle east coast populations the average weights were slightly less. In Area 7, and in the west coast of Vancouver Island populations, herring of each age-group were of approximately average weight. In most populations average lengths in 1954–55 differed little from the corresponding ten-year averages. However, herring in each age-group in the northern population were slightly longer than average, while those in the north central population were slightly smaller. The differences found from the ten-year averages are not such as would suggest that any major changes had occurred in 1954–55 in environmental conditions affecting growth.

Little difference existed in average length between fish from the winter and spawning samples in either the middle or lower east coast of Vancouver Island populations, although there was a tendency for fish in the middle east coast spawning samples to be slightly longer than those from the winter samples.

The average lengths and weights of herring in each age-group in the runs to Areas 2A-E and 2B-E in the Queen Charlotte Islands are shown below for each of the recent years in which there has been a fishery in this sub-district.

Fishing Season	Average Length (Mm.)					Average Weight (Gm.)				
	II	III	IV	V	VI	II	III	IV	V	VI
Area 2A-E										
1954–55	147	163	184	202	214	40	58	86	115	135
1953–54	133	165	176	197	208	25	51	67	93	—
Area 2B-E										
1953–54	—	179	197	205	221	—	63	98	105	151
1951–52	150	180	194	202	212	39	76	101	116	136
1950–51	—	178	190	199	207	..	67	85	99	114

The data indicate that in each age-group herring from Area 2A-E are smaller in average length than those from Area 2B-E. The difference is more pronounced among the younger age-classes. A similar but somewhat less distinct difference exists in average weight. These differences in average length and weight lend support to the evidence from tag-recovery that the herring in Area 2A-E and Area 2B-E form two essentially distinct populations.

EXTENT AND INTENSITY OF SPAWNING

Each year the fisheries officers of the Federal Department of Fisheries estimate the extent and intensity of herring-spawn deposition along the British Columbia coast. An independent survey by members of the Pacific Biological Station staff was carried out each year from 1947 to 1954 in the west coast of Vancouver Island sub-district, and in 1955 in the middle and lower east coast of Vancouver Island sub-districts and in contiguous American waters (San Juan Islands and Boundary Bay regions). The methods employed were the same as those of previous years (Tester and Stevenson, 1948). As spawning takes place shortly after the close of the fishery, the size of the spawning stock is equivalent to the size of the escapement from the winter fishery. The amount of spawn deposited forms an index of the relative size of this stock and of the initial size of the new year-class. Data from the spawn survey are also used to obtain information on the relationship between size of the spawning stock and size of the resulting year-class at recruitment.

The results of the 1955 spawn surveys have been presented by Outram (1955) in a separate report, and only a general review will be given here. All amounts of spawn are shown as statutory miles at a standard intensity of deposition. The length of each individual spawning is measured and the intensity of deposition estimated as one of five broad categories—very light, light, medium, heavy, and very heavy. For each statistical area, the total miles of spawn and the average intensity of deposition are obtained and converted to the equivalent mileage at a standard intensity (medium).

The total amount of spawn deposited (215.2 miles) in 1955, while slightly less than in 1954 (225.6 miles), was still above the average for the last ten years. Increases in spawn deposition over the 1954 level occurred in the northern (40 per cent), middle east coast (68 per cent), south central (8 per cent), and west coast (8 per cent) sub-districts. Marked decreases in spawn occurred in the Queen Charlotte Islands (50 per cent), upper east coast (36 per cent), and lower east coast (32 per cent) sub-districts. In spite of the marked decreases, spawning in the Queen Charlotte Islands sub-district was little below average, while spawning in the lower east coast sub-district remained, for the third consecutive year, considerably above average.

The increased deposition in the northern sub-district resulted from a spawning of 10.1 miles in a new location, Wilson Inlet, in Area 5. While spawning has been at a low level in Area 4 for the past two years, the decrease has been compensated for by large increases in Area 5. While in the middle east coast sub-district spawning decreased somewhat in 1954, it returned in 1955 to the relatively high level of previous years. Large spawnings along the Parksville-Deep Bay shore-line (Area 14) and at the head of Bute Inlet (Area 13) accounted for the increase. In the south central sub-district, slight increases occurred in Areas 7 and 9 and a pronounced increase in Area 8. In Area 10 there was a marked drop in spawn deposition. The marked increase in Area 8 resulted from a remarkable spawning over 7 miles long in Burke Channel at the beginning of July. Not only was this one of the largest spawnings recorded for the area, but, with the exception of small spawnings in Area 2A-E in the Queen Charlotte Islands, it was one of the first records of summer spawnings on the British Columbia coast. On the west coast of Vancouver Island the increase in spawn resulted from a substantial increase in Area 26, where a large new spawning occurred in the Spring Island region. The increase

in Area 26 more than offset a sharp decrease in spawning in Area 27. Spawning in other areas was about average.

In the Queen Charlotte Islands the decrease in spawning arose from the virtual failure of spawning in Area 2A-E and from a sharp decrease in Area 2B-E. The amount of spawn in Area 2B-E was approximately the same as in 1951, 1952, and 1953. In the upper east coast sub-district there was no spawning in Kingcome Inlet (Area 12) for the first time in ten years. In recent years between 1 and 3 miles of spawn have been recorded here. In the lower east coast sub-district, while spawning was reduced from the high level of the previous two years, it still remained above average. The lack of recurrent spawnings in the Yellow Point region (Area 17B) was largely responsible for the decrease. It is interesting to note the reappearance of a large spawning in Nanoose Bay (8.7 miles) after the almost complete failure of fish to spawn there in 1954.

The survey of American waters in the Boundary Bay and San Juan Islands regions revealed the presence of an exceptionally large and previously unreported spawning at Point Roberts. The spawning-ground was partly in Canadian waters and partly in American waters. Over a million square yards of spawn was recorded, making it one of the largest individual spawnings on the coast. On the basis of the 1955 survey, the San Juan Islands region would not appear to be an important spawning area. While several spawnings were found, these were small and of very light intensity.

DISCUSSION

In the previous sections of this report the 1953–54 data on catch statistics, age composition, and spawn deposition in the major herring populations have been reviewed and an analysis of the movement of herring between populations presented. In this section, information on the level of abundance of the major stocks derived from data in the previous sections is discussed.

In 1954–55, herring in British Columbia were generally less abundant than in the previous year. The stocks in Northern and Central British Columbia and on the west coast of Vancouver Island were principally affected. In contrast, abundance remained at a high level in the stocks in the Strait of Georgia.

In the northern sub-district a marked decline in catch, and in catch per unit of effort, occurred for the second year in succession. The quota was not exceeded or approximated for the first time since 1948–49. Spawn deposition in 1955, although showing an increase of 40 per cent over the reduced deposition of 1954, was little above average. This, coupled with the decline in catch, suggests that the level of abundance has declined. If the poor catch had been solely due to the failure of the fish to appear on the fishing-grounds prior to spawning, a much larger increase in spawn deposition would have been expected. The markedly reduced amount of spawn deposition in Area 4 for the second successive year occurring simultaneously with a marked increase in Area 5 suggests a possible southward shift in the centre of the spawning population.

In the central sub-district the quota was not taken for the second year in succession, and the catch was the lowest since 1946–47. The fishery was characterized by poor catches from the major migratory populations of Areas 6 and 7, usually the dominant contributors, and by a greater dependence on the local populations in all areas. Spawn deposition in Area 7, the major spawning region of the sub-district in recent years, was up to average; in Area 6, spawn deposition remained at the low level that has existed for the past four years and was the lowest recorded for the area. In Area 8, spawn deposition showed a sharp increase over 1954, due to the large summer spawning in Burke Channel. The significance of this apparently unusual spawning in terms of eventual recruitment to the stock is not known. Spawnings in Areas 9 and 10 were both below average. The low catch in this sub-district cannot, therefore, be accounted for by late inshore migration, and hence abundance must be at a generally low level throughout the sub-district and particularly in Area 6.

In the Queen Charlotte Islands sub-district the fishery took place almost entirely in Skidegate Inlet, in Area 2A-E, for the second successive year. Although the catch was almost as high as in 1953–54, much greater effort was expended in taking it. The fishery lasted for nine weeks, as compared to four weeks in 1953–54, and catch per unit of effort was one-third that in 1953–54. Although only relatively small spawnings have been reported in past years from this area, spawning in 1955 was negligible. It would thus appear that abundance had declined in this area in 1954–55, but possibly not to as low a level as in other populations in Northern and Central British Columbia.

On the west coast of Vancouver Island the catch in 1954–55 was the lowest since 1943–44. This is a marked contrast to 1953–54, when the catch was the highest since 1948–49. The low catch resulted from the sharply reduced fishery in Area 23 and the complete failure of the fishery in Area 25, the other major producing area, and in Area 24. In Area 27 the catch was a record and equalled that made in Barkley Sound. In spite of the poor fishery, spawning in all areas, except Area 27, was at least up to average. The apparent reduction in spawn deposition in Area 25 was due to an incomplete survey of the large Nuchatlitz spawning. Spawning in Area 26 was the highest on record. In Area 27, spawning was sharply reduced and was below average. The data on spawn deposition do not suggest that delayed inshore migration could have been a major cause of the poor fishery.

In the middle east coast and lower east coast of Vancouver Island sub-districts, in contrast to other sub-districts, abundance was at a high level. In the middle east coast sub-district a record catch of 24,650 tons was followed by a record spawning of 36.6 miles. In the lower east coast sub-district a nearly record catch of 51,300 tons was followed by an above-average spawning of 43.4 miles. The reduction in spawn deposition in this sub-district for the second year in succession from the exceeding high level of 1953 suggests that possibly some decline in abundance occurred from the very high level of the previous two years.

Thus, while population abundance was at a reduced or low level in 1954–55 in all major populations except those of the middle and lower east coast of Vancouver Island, spawn deposition in all populations appears to have been at least equal to the average for recent years, and should, therefore, be adequate to ensure the maintenance of the populations.

The reduced or low level of abundance in 1954–55 in all major populations except those of the middle and lower east coast of Vancouver Island is the result of the relative weakness of those year-classes contributing the III-, IV-, and V-year-old fish to the populations. Fish of Age V form a considerably smaller proportion of the population than either the III- or the IV-year-olds; their contribution is usually of more importance in northern populations than in southern populations. The 1952 year-class (III-year-olds) was weak in the Queen Charlotte Islands, northern, and north and south central populations. In these populations it made one of the smallest contributions for III-year-old fish for a number of years. On the west coast of Vancouver Island this year-class was possibly somewhat stronger, at least in the south west coast population, but was still of below-average strength. In the middle and lower east coast of Vancouver Island sub-districts the 1952 year-class was relatively strong. The 1951 year-class was considered to be stronger than the 1952 year-class in all populations. However, while it was of above-average strength in the middle and lower east coast of Vancouver Island populations, it was only of average strength on the west coast of Vancouver Island and of no more than average strength in the northern group of populations. The 1950 year-class appears to have been somewhat weaker than the 1951 year-class in all populations. Thus, in the Queen Charlotte Islands, northern and north and south central populations where dependence is primarily on fish of Ages III and IV, the year-classes contributing these fish were of weak and below-average strength. In the southern populations, dependence is principally on fish of Age III, with some support from fish of Age IV.

On the west coast of Vancouver Island the year-class providing the dominant III-year age-group was weak, although the year-class providing the IV-year fish was of average strength. In the middle and lower east coast both the 1952 and 1951 year-classes were of at least average and probably above-average strength.

In 1952, spawn deposition in the northern group of populations and on the west coast of Vancouver Island was sharply reduced. In the Queen Charlotte Islands sub-district it was 63 per cent below the average for the ten years 1946 to 1955, in the northern sub-district 33 per cent below, in the central sub-district as a whole 50 per cent below, and in the west coast of Vancouver Island sub-district 46 per cent below the ten-year average. While it is possible that the reduced amount of spawn deposited in 1952 might be the direct cause of the weakness of the 1952 year-class in these sub-districts, it is more probable that it was only a contributing factor, and that the weakness of this year-class resulted from poor survival during the critical early life-history stages. The results of the comparative study of the west coast of Vancouver Island and lower east coast of Vancouver Island populations have shown that variations in year-class strength are better explained by changes in environmental conditions, probably during the critical larval and post-larval period, than by changes in the amount of spawn deposited. Spawn deposition showed no relationship to future recruitment. For instance, on the west coast of Vancouver Island in 1947, 36.7 miles of spawn (adjusted to medium intensity) was deposited, 2.6 miles less than in 1952, yet the 1947 year-class was one of the strongest on record while the 1952 year-class was of below-average strength. On the other hand, in 1950, when 53.1 miles of spawn was deposited, one of the largest amounts recorded for the sub-district, the resulting year-class was of below-average strength. In the northern sub-district in 1952, spawning was only 20 per cent less than in 1947, yet there was great dissimilarity in the strengths of the resulting year-classes. The 1952 year-class was weak, while the 1947 was extremely powerful and contributed largely to the record catches of 1949-50, 1950–51, and 1951–52. In 1945 there were only 7.7 miles of spawn of medium intensity deposited, compared to 14.1 miles in 1952, yet the 1945 year-class was at least of average strength, for substantial catches were made in 1947–48 and 1948–49, the seasons when this year-class was present as III- and IV-year fish. It appears likely, therefore, that in the northern sub-district as well spawn deposition bears no direct relationship to resulting year-class strength. While no specific examples from the central and Queen Charlotte Islands sub-districts are available, it seems reasonable to assume that no direct relationship exists in these populations between spawn deposition and year-class strength, and that variations in year-class strength result primarily from the effect of natural factors on survival. It appears likely, therefore, that the relative weakness of the 1952 year-class in Northern and Central British Columbia and on the west coast of Vancouver Island was caused not so much by the poor spawnings in 1952 as by poor survival conditions during the first year of life.

In all sub-districts except the upper east coast of Vancouver Island the proportion of II-year fish in the catches in 1954–55 was higher than in 1953–54. This may indicate that the 1953 year-class is stronger than the 1952 year-class. However, the proportion of II-year fish is not always a reliable indication of the strength of the year-class when it is fully recruited. It has been found to be a better indication in the west coast of Vancouver Island populations than in others. It is probably somewhat more reliable in southern populations than in the northern where a greater proportion of the recruitment takes place at Age IV. The success of the fishery in all sub-districts will depend to a large extent on the strength of the 1953 year-class. If it proves stronger than the 1952 year-class, an improvement in the fishery should result.

SUMMARY

A general review of the status of the major British Columbia herring stocks in 1954–55 has been presented.

The catch (169,163 tons) in 1954–55 was the poorest since 1946–47. Record or near-record high catches were made in the upper east coast of Vancouver Island, middle east coast of Vancouver Island, and lower east coast of Vancouver Island sub-districts. The catch in the Queen Charlotte Islands sub-district was less than the record catch of 1953–54. Catches in the northern, central, and west coast sub-districts were sharply reduced.

While population abundance was at a high level in the middle and lower east coast sub-districts, it was at a low level in the northern, central, and west coast of Vancouver Island sub-districts. In the Queen Charlotte Islands sub-district, population abundance was considerably lower than in the previous year. Population abundance in Area 12 of the upper east coast sub-district was probably also below normal. The high catch in this sub-district resulted from the exploitation of a new fishing-ground in Seymour Inlet and Nugent Sound.

The low level of population abundance in the northern, central, and west coast of Vancouver Island sub-districts and the reduced level of abundance in the Queen Charlotte Islands sub-district resulted from the poor contributions of III-year fish by the 1952 year-class. The 1951 year-class (IV-year fish) was probably of below-average or no more than average strength in the northern group of populations. On the west coast of Vancouver Island this year-class was probably stronger than in the north, but was still probably of only average strength. Both the 1951 and 1952 year-classes were stronger in the south west than in the north west coast of Vancouver Island areas. In the middle and lower east coast of Vancouver Island the 1952 year-class was also somewhat weaker than the 1951 year-class, but both were probably of above-average strength.

The proportion of II-year fish in all sub-districts, except the upper east coast of Vancouver Island, in 1954–55 was greater than in 1953–54. This may indicate that the 1953 year-class will be somewhat stronger than the 1952 year-class.

Spawn deposition in 1955 was greater than in 1954 in the northern, central, middle east coast, and west coast of Vancouver Island sub-districts. In the Queen Charlotte Islands, upper east coast, and lower east coast of Vancouver Island sub-districts it was less than in 1954. In the latter sub-district it was, however, still above average. The level of spawn deposition in all sub-districts appears adequate to ensure the maintenance of the populations.

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Pilot-house record-books, which provided much valuable information on the catch and the fishery, were again kept by most of the seiner captains. It is with great pleasure that we acknowledge this support and the continued interest of all herring-fishermen in the research programme.

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The interest of the Provincial Department of Fisheries and its Deputy Minister, G. J. Alexander, in continuing the publication of this series of reports is gratefully acknowledged. This report is the nineteenth of the series.

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G. T. Taylor acted as administrative assistant of the herring investigation. He was responsible for the compilation and analysis of the catch data and for the compilation and preliminary analysis of the tag-recovery data. R. S. Isaacson, laboratory technician, was responsible for the age determinations of all fish from the winter and spawning samples. In addition, he supervised the compilation of age and growth data and contributed to their preliminary analysis. His assistance in assembling this report is also gratefully acknowledged.

All members of the investigation assisted in some phase of the field work. J. S. Rees was responsible for the supervision of the tag-recovery and sampling programmes and was in charge of the field crew in Steveston. Other members of the investigation, B. Wildman, W. P. Neave, E. W. Stolzenberg, A. Rigby, and D. Pozar, assisted in the field programme and in the preliminary analysis of the data. Miss Elizabeth Neave and Miss Naomi Johnson provided invaluable assistance during the summer in the compilation of current and past years' sampling data. Miss Diane Blackburn ably carried out stenographic and clerical duties for the investigation.

M. A. Pirart continued work in the design and operation of tag-detectors. R. M. Wilson, port contact man in Vancouver, arranged for the collection of certain samples.

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Table I.—Tags Inserted during the 1955 Spawning Season

Code Letters	Tagging Code	Place	Date	Number
		Area 13		
HSH	19A	Frederick Point, Read Island	Mar. 25, 1955	496
HTH	19A	Frederick Point, Read Island	Mar. 25, 1955	513
HXH	19A	Frederick Point, Read Island	Mar. 25, 1955	491
		Area 14		
EKE	19B	French Creek	Mar. 13, 1955	492
ELE	19B	French Creek	Mar. 13, 1955	496
EME	19B	French Creek	Mar. 13, 1955	495
ENE	19C	Goose Spit	Mar. 17, 1955	479
EOE	19C	Goose Spit	Mar. 17, 1955	493
HUH	19C	Goose Spit	Mar. 17, 1955	498
		Area 15		
HYH	19D	Junction Point, Lewis Channel	Mar. 25, 1955	509
HZH	19D	Junction Point, Lewis Channel	Mar. 25, 1955	500
IAI	19D	Junction Point, Lewis Channel	Mar. 25, 1955	507
IBI	19E	Scuttle Bay	Mar. 26, 1955	501
ICI	19E	Scuttle Bay	Mar. 26, 1955	492
IDI	19E	Scuttle Bay	Mar. 26, 1955	501
		Area 17A		
KIK	19F	Nanoose Bay	Apr. 22, 1955	502
KJK	19F	Nanoose Bay	Apr. 22, 1955	501
KKK	19F	Nanoose Bay	Apr. 22, 1955	506
LAL	19G	Departure Bay	Apr. 6, 1955	506
LBL	19G	Departure Bay	Apr. 6, 1955	506
LCL	19G	Departure Bay	Apr. 6, 1955	504
		Area 17B		
KAK	19H	Coffin Point	Mar. 4, 1955	458
KBK	19H	Coffin Point	Mar. 4, 1955	477
KCK	19H	Coffin Point	Mar. 4, 1955	489
KLK	19J	North Cove, Thetis Island	Mar. 11, 1955	500
KMK	19J	North Cove, Thetis Island	Mar. 11, 1955	529
KNK	19J	North Cove, Thetis Island	Mar. 11, 1955	521
KDK	19K	Ladysmith Harbour	Mar. 20, 1955	506
KEK	19K	Ladysmith Harbour	Mar. 20, 1955	498
KHK	19K	Ladysmith Harbour	Mar. 20, 1955	536
KOK	19L	Preedy Harbour, Thetis Island	Apr. 1, 1955	512
KPK	19L	Preedy Harbour, Thetis Island	Apr. 1, 1955	493
		Area 18		
JEJ	19M	Finlayson Arm	Apr. 18, 1955	503
JHJ	19M	Finlayson Arm	Apr. 18, 1955	497
JIJ	19M	Finlayson Arm	Apr. 18, 1955	498
		Total		17,505

Table II.—Number of Tags Recovered by Tag-detectors, according to Area of Tagging and Area of Recovery, for the 1954–55 Fishing Season

Area of Tagging	Area of Recovery						Total Number of Recoveries
	6	8	13	17B	18	27	
4	1	—	—	—	—	—	1
6	1	—	—	—	—	—	1
7	—	1	—	—	—	—	1
15	—	—	1	—	—	—	1
17A	—	—	—	1	1	—	2
17B	—	—	—	—	6	—	6
18	—	—	—	—	11	—	11
23	—	—	—	—	1	—	1
24	—	—	—	—	1	—	1
25	—	—	—	—	—	2	2
27	—	—	—	—	—	2	2
Totals	2	1	1	1	20	4	29

Table III.—Number of Tags Recovered by Plant Crews, according to Area of Tagging and Probable Sub-district of Recovery, for the 1954–55 Fishing Season

Sub-district and Area of Tagging	Tagging Code	Year of Tagging	Probable Sub-district of Recovery										Total
			Q.C.I.	Northern	North Central	South Central	Upper East Coast	Middle East Coast	Lower East Coast	South West Coast	North West Coast	?	
Queen Charlotte Islands													
Area 2A-E	18T	1954	173	4	—	—	—	—	—	—	—	51	228
	18U	1954	282	17	—	—	—	—	—	—	—	86	385
	18W	1954	142	5	—	—	—	—	—	—	—	34	181
Area 2B-E	16CC	1952	2	2	—	—	—	—	—	—	—	4	8
	17QQ	1953	3	2	—	—	—	1	—	—	—	2	8
	17RR	1953	—	1	—	—	—	1	—	—	—	4	6
	18S	1954	—	7	—	—	—	—	—	—	—	9	16
Northern													
Area 4	15T	1951	1	1	—	—	—	—	—	—	—	1	3
	15U	1951	—	5	—	—	—	—	—	—	—	2	7
	16Z	1952	—	7	—	—	—	—	—	—	—	2	9
	16AA	1952	—	8	—	—	—	—	—	—	—	3	11
	16BB	1952	2	—	—	—	—	—	—	—	—	1	3
	17MM	1953	5	47	—	—	—	—	—	—	—	6	58
	17NN	1953	2	24	—	—	—	—	—	—	—	9	35
	17PP	1953	—	29	1	—	—	—	—	—	—	5	35
	18P	1954	—	16	—	—	—	—	—	—	—	2	18
	18Q	1954	—	78	—	1	—	—	—	—	—	7	86
	18R	1954	5	153	3	—	—	—	—	—	—	44	205
Area 5	18N	1954	1	147	3	—	—	1	—	—	—	23	175
North Central													
Area 6	14AA	1950	—	1	—	—	—	—	—	—	—	—	1
	14BB	1950	—	—	—	—	—	—	—	—	—	1	1
	15V	1951	—	2	—	—	—	—	—	—	—	2	4
	15W	1951	—	4	1	—	—	—	—	—	—	1	6
	17LL	1953	—	1	3	3	—	—	—	—	—	5	12
	18M	1954	—	7	15	9	—	—	—	—	—	11	42
South Central													
Area 7	14KK	1950	—	—	—	1	—	—	—	—	—	—	1
	15AA	1951	—	—	—	1	—	—	—	—	—	—	1
	15BB	1951	—	—	—	2	—	—	—	—	—	—	2
	16U	1952	—	—	1	—	—	—	—	—	—	3	4
	16W	1952	—	—	—	5	—	—	—	—	—	1	6
	16X	1952	—	1	—	1	—	—	—	—	—	3	5
	16Y	1952	—	—	—	6	—	—	—	—	—	3	9
	17EE	1953	—	1	—	4	—	—	—	—	2	11	18

Table III.—Number of Tags Recovered by Plant Crews, according to Area of Tagging and Probable Sub-district of Recovery, for the 1954–55 Fishing Season—Continued

Sub-district and Area of Tagging	Tagging Code	Year of Tagging	Probable Sub-district of Recovery										Total
			Q.C.I.	Northern	North Central	South Central	Upper East Coast	Middle East Coast	Lower East Coast	South West Coast	North West Coast	?	
	17FF	1953	—	1	—	5	—	2	—	—	1	5	14
	17GG	1953	1	—	—	10	—	1	—	—	—	14	26
	17HH	1953	—	—	—	2	—	—	—	—	—	6	8
	17II	1953	—	—	—	1	—	1	—	1	—	2	5
	17KK	1953	1	—	—	4	—	2	—	—	1	3	11
	18K	1954	—	—	5	10	—	2	—	—	—	10	27
	18L	1954	—	—	3	14	—	1	—	—	—	17	35
Area 10	14EE	1950	—	—	—	—	—	1	—	—	—	2	3
	15CC	1951	—	—	1	—	—	2	—	—	—	1	4
Upper East Coast													
Area 12	9J	1945	—	—	—	—	1	—	—	—	—	—	1
	17DD	1953	—	—	—	—	10	16	—	—	2	7	35
Middle East Coast													
Area 13	10S	1946	—	—	—	—	—	1	—	—	—	—	1
Area 14	14A	1950	—	—	—	—	—	1	—	—	—	—	1
	16A	1952	—	—	—	—	—	9	1	—	—	2	12
	17B	1953	—	1	—	—	—	6	—	—	—	—	7
	17C	1953	—	—	—	—	—	1	—	—	—	—	1
	18C	1954	—	1	—	—	—	11	—	—	—	2	14
Area 15	14B	1950	—	—	—	—	—	2	—	—	—	—	2
	14C	1950	—	—	—	—	—	2	—	—	—	—	2
	15A	1951	—	—	—	—	—	4	—	—	—	2	6
	15B	1951	—	—	—	—	—	5	—	—	—	1	6
	17A	1953	—	—	1	—	—	28	—	—	—	7	36
	18A	1954	—	—	—	—	—	45	1	—	—	10	56
Lower East Coast													
Area 17A	15C	1951	—	—	—	—	—	—	—	—	—	2	2
	15D	1951	—	—	—	—	—	1	—	—	—	—	1
	16C	1952	—	—	—	—	—	1	—	—	—	—	1
	16D	1952	—	—	—	—	—	1	2	—	—	1	4
	17D	1953	—	—	—	—	—	3	2	—	—	—	5
	17E	1953	—	—	—	—	—	1	—	—	—	1	2
	18C	1954	—	—	—	—	—	27	24	—	—	19	70
Area 17B	14H	1950	—	—	—	—	—	—	1	—	—	—	1
	16F	1952	—	—	—	—	—	1	5	—	—	—	6
	16G	1952	—	—	—	—	—	1	2	—	—	—	3
	17F	1953	—	—	—	—	—	—	2	—	—	—	2
	17G	1953	—	—	—	—	—	—	1	—	—	1	2
	17I	1953	—	—	—	1	—	—	2	—	—	1	4
	18D	1954	—	—	—	—	—	6	30	—	—	4	40
Area 18	15F	1951	—	—	—	—	—	—	7	—	—	4	11
	15G	1951	—	—	—	—	—	—	—	—	—	1	1
	17J	1953	—	—	—	—	—	—	—	—	—	4	4
	18E	1954	—	—	—	—	—	3	31	1	1	12	48
	18F	1954	—	—	—	—	—	4	39	—	—	3	46
South West Coast													
Area 23	13H	1949	—	—	—	—	—	—	—	—	—	1	1
	16I	1952	—	—	—	—	—	—	—	—	1	1	2
	16J	1952	—	—	—	—	—	2	—	1	—	—	3
	16K	1952	—	—	—	1	—	1	1	—	—	1	4
	17K	1953	—	—	—	—	—	—	1	—	—	6	7
	17M	1953	—	—	—	—	—	—	2	1	—	6	9
	17N	1953	—	—	—	—	—	—	3	1	1	4	9
	17P	1953	—	—	—	—	—	—	—	1	1	2	4
	17R	1953	—	—	—	—	—	—	—	—	1	—	1
	17S	1953	—	—	—	—	—	—	1	—	—	3	4
Area 24	16M	1952	—	—	—	—	—	1	—	—	1	2	4
	17T	1953	—	—	—	—	—	—	2	—	—	2	4
	17U	1953	—	—	—	—	—	—	1	—	1	1	3
	18G	1954	—	—	—	—	—	—	—	1	1	5	7

Table III.—Number of Tags Recovered by Plant Crews, according to Area of Tagging and Probable Sub-district of Recovery, for the 1954–55 Fishing Season—Continued

Sub-district and Area of Tagging	Tagging Code	Year of Tagging	Probable Sub-district of Recovery										Total
			Q.C.I.	Northern	North Central	South Central	Upper East Coast	Middle East Coast	Lower East Coast	South West Coast	North West Coast	?	
North West Coast													
Area 25	14R	1950	—	—	—	—	—	1	—	—	—	—	1
	15Q	1951	—	—	—	—	—	—	—	—	—	1	1
	16R	1952	—	—	—	—	—	—	—	—	—	2	2
	17W	1953	—	—	—	—	—	—	—	—	1	—	1
	17Y	1953	—	—	—	—	—	—	—	—	—	1	1
	17Z	1953	—	—	—	—	—	—	—	—	—	1	1
	18H	1954	—	—	—	—	—	—	2	—	1	6	9
	18J	1954	—	—	—	—	—	—	1	—	3	4	8
Area 26	14V	1950	—	—	—	—	—	—	—	—	—	1	1
	14W	1950	—	—	—	—	—	—	—	—	1	—	1
	16T	1952	—	—	—	—	—	1	—	—	3	2	6
	17X	1953	—	1	—	—	—	—	—	—	—	1	2
	17AA	1953	—	—	—	—	—	—	—	—	6	2	8
	17BB	1953	—	—	—	—	—	—	—	—	2	3	5
Area 27	12X	1948	—	—	—	—	—	—	—	—	1	1	2
	14X	1950	—	—	—	—	—	—	—	—	1	3	4
	17CC	1953	—	—	—	—	1	—	—	2	13	3	19
Totals			620	574	37	81	12	201	164	9	46	545	2,289

Table IV.—Probable Number of Tags in the Catches during the 1954–55 Season, Based on Magnet Recoveries, Shown by Area of Tagging and Probable Sub-District of Recovery, with Actual Number of Tags in Parentheses.

Sub-district and Area of Tagging	Probable Sub-district of Recovery									Total
	Queen Charlotte Islands	Northern	North Central	South Central	Upper East Coast	Middle East Coast	Lower East Coast	South West Coast	North West Coast	
Queen Charlotte Islands										
Area 2A-E	975 (723)	34 (22)	—	—	—	—	—	—	—	1,009 (745)
Area 2B-E	9 (6)	32 (23)	—	—	—	2 (2)	—	—	—	43 (31)
Northern										
Area 4	23 (14)	611 (402)	5 (4)	4 (2)	—	—	—	—	—	643 (422)
Area 5	2 (1)	239 (155)	4 (3)	—	—	1 (1)	—	—	—	246 (160)
North Central										
Area 6	—	26 (17)	33 (29)	35 (17)	—	—	—	—	—	94 (63)
South Central										
Area 7	2 (2)	3 (3)	19 (17)	275 (119)	—	14 (13)	—	1 (1)	8 (6)	322 (161)
Area 10	—	—	1 (1)	1 (1)	—	5 (5)	—	—	—	7 (7)
Upper East Coast										
Area 12	—	—	—	—	14 (12)	22 (21)	—	—	4 (3)	40 (36)
Middle East Coast										
Area 13	—	—	—	—	—	1 (1)	—	—	—	1 (1)
Area 14	—	2 (2)	—	—	—	31 (31)	2 (2)	—	—	35 (35)
Area 15	—	—	1 (1)	—	—	114 (106)	1 (1)	—	—	116 (108)
Lower East Coast										
Area 17A	—	—	—	—	—	42 (40)	53 (45)	—	—	95 (85)
Area 17B	—	—	—	2 (1)	—	10 (10)	56 (47)	—	—	68 (58)
Area 18	—	—	—	—	—	8 (8)	120 (99)	2 (2)	1 (1)	131 (110)
South West Coast										
Area 23	—	—	—	2 (1)	—	5 (5)	9 (9)	26 (25)	4 (4)	46 (44)
Area 24	—	—	2 (2)	—	—	1 (1)	4 (4)	6 (6)	6 (5)	19 (18)
North West Coast										
Area 25	—	—	—	—	—	1 (1)	9 (9)	—	17 (14)	27 (24)
Area 26	—	2 (2)	—	—	—	1 (1)	—	—	24 (20)	27 (23)
Area 27	—	—	—	—	1 (1)	—	—	2 (2)	30 (22)	33 (25)
Totals	1,011 (746)	949 (626)	65 (57)	319 (141)	15 (13)	258 (246)	254 (216)	37 (36)	94 (75)	3,002[1] (2,156)

[1] This total does not include 133 tags recovered at Fairview plant as no magnet efficiency tests were made at this plant.

Table V.—Number of Statutory Miles of Spawn, Adjusted to Medium Intensity, by Area and Years

Sub-district and Area	Statutory Miles of Spawn of Medium Intensity				
	1951	1952	1953	1954	1955
Queen Charlotte Islands					
Area 2A-E	1.5	0.8	3.2	1.9	—
Area 2B-E	6.5	4.6	10.2	20.2	11.3
Totals	8.0	5.4	13.4	22.1	11.3
Northern					
Area 3 (Nass)	3.2	1.6	0.9	0.5	—
Area 4 (Skeena)	14.5	11.6	16.1	5.4	4.3
Area 5 (Grenville)	7.2	0.9	3.3	10.5	18.8
Totals	24.9	14.1	20.3	16.4	23.1
North Central					
Area 6 (Butedale)	11.8	4.3	6.8	4.7	4.0
South Central					
Area 7 (Bella Bella)	28.6	17.7	29.4	28.0	28.2
Area 8 (Bella Coola)	0.5	1.5	0.2	2.7	8.9
Area 9 (Rivers Inlet)	2.1	0.8	4.2	0.4	1.1
Area 10 (Smith Inlet)	3.3	2.8	9.2	5.8	1.6
Totals	34.5	22.8	43.0	36.9	39.8
Upper East Coast of Vancouver Island					
Area 11 (Seymour Inlet)	0.1	0.2	—	0.4	—
Area 12 (Alert Bay)	14.2	9.7	24.7	14.0	9.2
Totals	14.3	9.9	24.7	14.4	9.2
Middle East Coast of Vancouver Island					
Area 13 (Quadra Island)	2.6	6.0	5.8	3.2	12.2 (13.8)
Area 14 (Comox)	22.4	24.4	23.7	11.4	19.0 (21.0)
Area 15 (Powell River)	3.4	2.3	3.0	2.4	1.4 (1.6)
Area 16 (Pender Harbour)	2.7	3.4	3.2	4.8	4.0 (4.0)
Totals	31.1	36.1	35.7	21.8	36.6 (40.4)
Lower East Coast of Vancouver Island					
Area 17A (Nanaimo)	12.2	7.8	17.6	0.8	9.0 (9.4)
Area 17B (Ladysmith)	5.8	20.4	82.4	61.5	[1]6.5 (28.8)
Area 18 (Ganges Harbour)	0.3	2.0	2.5	1.9	1.4 (5.2)
Area 19 (Victoria)	0.1	0.1	—	—	— —
Totals	18.4	30.3	102.5	64.2	16.8 (43.4)
West Coast of Vancouver Island					
Area 23 (Barkley Sound)	4.1 (8.3)	4.8 (9.8)	7.8 (13.1)	4.6 (11.0)	5.6
Area 24 (Clayoquot Sound)	6.5 (3.0)	4.9 (2.4)	7.0 (7.8)	4.2 (4.5)	4.7
Area 25 (Esperanza Inlet)	9.5 (34.1)	2.8 (26.6)	11.4 (36.4)	7.1 (17.5)	6.9
Area 26 (Kyuquot Sound)	1.5 (1.0)	0.9 (1.6)	4.4 (8.0)	3.2 (4.8)	8.6
Area 27 (Quatsino Sound)	4.9 (5.1)	1.2 (1.3)	10.8 (11.5)	7.2 (7.3)	2.6
Totals	26.5 (51.5)	14.6 (41.7)	41.4 (76.8)	26.3 (45.1)	28.4
United States					
San Juan Islands-Boundary Bay	— —	— —	— —	— —	— (15.6)
Grand totals, all areas	169.0 (194.5)	137.5 (164.6)	287.8 (323.2)	206.8 (225.6)	169.2 (215.2)

[1] Complete coverage by fishery officers impossible because boat not available.

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Problems in the Control of

OXIDATIVE RANCIDITY IN FROZEN FISH

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Development of oxidative rancidity is responsible for much of the deterioration which occurs in frozen fish and meats, and in both instances the same basic causes are operative. However, fish is far more susceptible to this type of spoilage than are meats because of the very unsaturated nature of the fatty acid components of fish oils. The writer outlines the work which has been carried out to determine the catalytic nature of the oxidation of the oils in fish flesh, the measures which are taken to suppress this oxidation, and the need for further research.

The principal known causes of fish deterioration are microbial spoilage, protein denaturation, and development of oxidative rancidity. While the first named change is one that is primarily of importance in fresh fish, the two last named changes occur largely with stored frozen fish, and these became important with the advent of large-scale refrigerated storage of this commodity. Development of oxidative rancidity in frozen fish is accompanied by undesirable odors and flavors, and by visible alterations such as oxidation with concomitant fading of red salmon pigments and so called "rusting" of exposed lipids. Since the lipids of fatty fish contribute much to desirable flavors, even a slight oxidation of these may occasion serious flavor defects.

Active interest in the mechanism of oxidation of fats in cold stored fish and its control appears to have originated from the work of Banks [1]. He found that the rate of oxidation of herring oil emulsions, stored at −10°C. for up to 71 days, was

NOTE—This paper represents part of the subject matter of an address given to a meeting of the Winnipeg Section of the Canadian Food Technologists Association, October 1954.

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strongly stimulated by addition of sodium chloride and of heated and unheated muscle. Thus, as judged by peroxide and Kreis values, the following increasing oxidation rates were found: heated muscle, heated muscle + NaCl, unheated muscle and unheated muscle + NaCl. Banks suggested that herring muscles may contain a heat labile enzyme that accelerates fat oxidation. At about the same time Lea [12] studied post-mortem oxidation of pork fats and showed that enzyme extracts of lipoid tissues contained an oxidase capable of oxidizing p-phenylenediamine, guaiacum, and similar phenolic or aromatic amino compounds to colored quinoidal derivatives. He also showed that pork muscle contained a system rather similar to that of herring muscle; for the former catalyzed oxidation of pork fats and its activity was accelerated by NaCl and depressed by heat. Lea did not present direct proof that the polyphenol oxidase was itself involved in fat oxidation. At the time, neither of the above investigators apparently attached any significance to the earlier observation of Robinson [14]. She had shown that haemoglobin, methaemoglobin and haemin all catalyzed oxidation of linseed oil emulsions, but that iron-free haematoporphyrin did not. Inorganic iron also catalyzed this oxidation, but was considerably less effective. It is interesting to note that she was the first to use a manometric technique to determine the rate of fat oxidation.

Banks [8] was apparently the first to recognize that "haem"—compounds might be at least partly responsible for oxidation of fats in fish muscle. In work carried out prior to 1939, the publication of which was delayed by the War, he showed by manometric technique that linoleic acid was oxidized rapidly by various "haem"-compounds. The relative effectiveness of these compounds in order of increasing activity was: haemoglobin, haematin, metmyoglobin, methaemoglobin, cytochrome C and pyridine haemochromogen. Potassium cyanide in 0.002M concentration caused about 66% reduction of the catalytic activity of the natural pigments, but only 33% of that of haemin and pyridine haemochromogen. Comparatively high concentrations of NaCl activated both haemoglobin and methaemoglobin. Free iron and copper had very little effect on the oxidation of linoleic acid.

The effect of herring muscle on oxidation of linoleate was investigated by Kahn [11]. He extracted a crude enzyme preparation, which he termed "lipoxidase", from the dark lateral muscle of herring. This "enzyme", when further purified, was only active in the presence of certain "activators", which he isolated from the muscle and which appeared to be myglobin and cytochrome C. The exact nature of the "lipoxidase" enzyme was not determined and it is unfortunate that he did not apparently measure the catalytic activity of the activators when used alone, as well as when used in conjunction with the enzyme. This makes it impossible to know what proportion, if any, of the activity was occasioned by the enzyme, or, in fact, whether such an enzyme exists. Previous work, as stated above, had already shown that the activators described by Kahn were themselves active catalysts in linoleate oxidation.

Watts and Peng [20] published the results of a study of development of oxidative rancidity in pork sausage, in which they showed that the raw product was much more susceptible to this change than when it was subjected to heating, as in cooking. They also showed that rancidity development was more rapid when the pH of the muscle was lower. In subsequent work, Watts and Peng [21] showed that the reduction in the rate of fat peroxidation due to heating was presumably linked up with the denaturation of the protein portion of the myoglobin molecule. They also found that there were two activity optima for fat peroxidation by pork muscle, namely pH 5 and pH 9. They concluded that, since the magnitude of the peroxidizing effect of pork muscle extracts is only slightly less than that of haemoglobin, the lipoxidase activity of pork muscles depends on its haemoglobin or myglobin content. They found that cyanide did not inhibit the oxidation at pH 5.3. Watts and Peng concluded that the reduction of the catalytic activity of myo-

globin that occurred on heating was due to protein coagulation and thus to removal of the "haem"-nucleus from intimate contact with unsaturated fats.

In this field the recent work of Tappel [15] supports the conclusions of Watts and Peng. Thus, from studies on the catalytic effect of crystalline haemin added to pork muscle extract, he concluded that loss of activity brought about by heating muscle extracts was due to removal of haemin by heat coagulation of the proteins, rather than to removal of a heat-labile enzyme. He stated that past attemps to demonstrate the presence or absence of a lipoxidase in pork tissues were inconclusive because of the difficulty of separating fat oxidation catalyzed by "haem"-compounds from that catalyzed by hypothetical enzymes. Previous investigators had shown that haemin only catalyzed the peroxidation of colloidal or heterogeneous linoleate suspensions, and not of homogeneous ones. True lipoxidase is active in oxidizing both homogeneous and heterogeneous linoleate and it was therefore concluded that such systems could be used to determine the possible content of a lipoxidase type of enzyme in animal tissues. If these were devoid of lipoxidase, homogeneous linoleate presumably would not be oxidized. The results of a number of experiments with mammalian tissues, and with muscle of seven species of fish, indicated that heterogeneous linoleate only was oxidized to an important extent, and that the muscles of the more fatty fish were most active in this respect. From these results, it would appear that "haem"-compounds are probably largely or entirely responsible for linoleate oxidation by fatty extracts. However, Tappel [15] showed that tissue extracts caused more pronounced oxidation than might be expected from their "haem"-content alone, and accordingly did not entirely exclude the possibility that muscle contains a catalyst capable of oxidizing homogeneous lineoleate.

Recently, Boyd and Adams [7] showed that, at pH 9.0, cyanide inhibits linoleate oxidation catalyzed by animal tissue, and this was taken to indicate "haem"-catalysis, since soybean lipoxidase is not so inhibited. The possibility that animal tissues contain a "lipoxidase" that is sensitive to cyanide was not overlooked, but attempts to isolate such an enzyme failed. Recently, Collier and McRae [8] concluded that stimulation of oxidation of linoleate at pH 7.0 by haemolysates of human erythrocytes was due to haemoglobin and not to a "lipoxidase" action. It would seem that it is doubtful that a true "lipoxidase" enzyme occurs in animal tissues.

Prevention of development of oxidative rancidity in frozen fish has been previously investigated. Banks [1] demonstrated that fat oxidation in herring muscle is accelerated by pure NaCl and later [2] that it proceeded more slowly at −28°C. than at higher temperatures. Since this initial observation the value of low storage temperatures in retarding fat oxidation in frozen fish has been reaffirmed repeatedly by other investigators. Preliminary storage at rather elevated temperatures (e.g. −2.5 or −10°C.) caused a delay in subsequent fat oxidation at lower storage temperatures and this may have been due to denaturation of the proteins of myglobin or of cytochrome.

Methods of retarding rancidity development in frozen fish were initiated at the Pacific Fisheries Experimental Station in 1944 and were carried on for several years [16, 17, 18]. Since the rather scanty literature then available was reviewed it will not be mentioned here. A study was made of various antioxidants, storage temperatures and physical conditions on development of oxidative rancidity in certain Pacific fish. Peroxide determinations were used as comparative criteria of fat oxidation in most instances, but reflectance measurements of the red color of salmon proved useful with these fish since the carotenoid pigments fade markedly in surface layers. The value of a good ice glaze in retarding development of rancidity was confirmed.

A number of antioxidants were studied both by dipping fillets into their solutions and by incorporating them into minced flesh. Only ethyl

gallate and 1-ascorbic acid conferred any useful protection and furthermore they could be applied readily because of their water solubilities. Storage of fish in nitrogen was the most effective measure by which rancidity was prevented, while storage in carbon dioxide, although effective in preventing rancidity, caused an unpleasant flavor. It was found that only the cyclic carbonyl enediols, namely 1-ascorbic acid, d-iso-ascorbic acid and reductic acid were effective as antioxidants for frozen fish. By contrast, the acyclic carbonyl enediols investigated, namely dihydroxymaleic acid and reductone, were ineffective. The reason for this was not established but it was suggested that it might be due either to inability of the straight chain compounds to take up oxygen at low (freezing) temperatures, or that hydrogen peroxide formed as they oxidized and that this tended to cancel the protective effect. It has been observed that ascorbic acid is not always consistent in its ability to retard development of oxidative rancidity in fish. That the *post-mortem* age of fish when treated has little influence on subsequent development of rancidity in the frozen product is indicated in recent work [19].

There has been some uncertainty regarding the value of ascorbic acid as a commercial antioxidant for frozen fish. It was originally pointed out [17] that it is desirable to maintain a rather high level (e.g., 0.05%) in fish flesh if really effective antioxidant activity is desired. It is doubtful whether the immersion procedures that have been recommended for industrial application usually result in treated fillets absorbing more than 0.02 to 0.03% [6]. Moreover, if the fish are not frozen soon after treatment, a significant loss of ascorbic acid will occur. Various methods of applying ascorbic acid have been proposed, such as a brief immersion in 1 or 2% aqueous solutions, or in 0.5% solutions that have been thickened with 0.5 to 1.0% of carrageen, carboxymethylcellulose or other agent, and glazing whole fish or steaks with ascorbic acid glaze.

The report of the 1950 Bergen Herring Conference [10] records trials with antioxidants used in attempts to retard fat oxidation in cold stored herring. In this report, Norwegian investigators reported very successful results with ascorbic acid as an antioxidant for Norwegian winter herring, while investigators from Torry Research Station found that this substance merely retarded increase in peroxide values and did not improve flavor of frozen herring. The latter group also observed that ascorbic acid conveyed an unpleasant astringent flavor to herring, which fact was not observed by the Norwegians. Banks [5] published, in detail, the results of the work on antioxidants that he presented at the above conference.

There have been additional brief published and unpublished reports concerning the value of ascorbic acid as an antioxidant for frozen fish or shellfish, but for the sake of brevity these will not be considered in detail. They have included the following information: (1) the quality and color of pink salmon fillets are somewhat improved; (2) the quality of frozen, glazed oysters is not improved; (3) the appearance and quality of frozen lobsters is improved; and (4) there was an improvement in quality of frozen salmon fillets as judged by peroxide values but not by organoleptic tests. It is of interest that an ascorbic acid-carrageen solution has been used for about four years on most of the fillets produced by one large company in British Columbia. It is hoped that further work will be carried out with ascorbic acid alone and in combination with other antioxidants.

Butylated hydroxyanisole (BHA) and more recently, butylated hydroxytoluene (BHT) are finding increased use in certain foods as antioxidants. In unpublished experiments our own work has shown that BHA alone, or in combination with propyl gallate and citric acid, affords less protection of frozen fish against development of oxidative rancidity than does ascorbic acid. On tre other hand, these compounds, or appropriate synergistic antioxidant mixtures containing them, offer promise in preparation of pre-cooked fish products such as "fish-sticks". Undoubtedly

these compounds are being used in the frying fats or breading mixtures used for such products, but no published information concerning the most effective synergistic mixtures appears to be available.

It has long been known that wood smoke has valuable antioxidant properties, but it is hard to say when the first reports concerning this effect were published. Oya [18] found that wood smoke, wood tar and creosote all retarded oxidation in fish oils. Banks [4] found that smoked herring gave a better dehydrated product than the untreated fish because it hindered development of rancid and allied off-flavors. Watts and Faulkner [22] found that several commercial "liquid wood smokes" exhibited marked antioxidant properties in aqueous lard systems. In ground, frozen pork, ascorbic acid (0.1%) accelerated fat oxidation, BHA retarded it somewhat, and liquid smoke (0.04%) exerted a still more pronounced protective effect. Further work showed that a mixture of liquid smoke plus ascorbic acid was much more effective than the liquid smoke alone. This finding is of interest in view of previous reports that ascorbic acid is effective as a fat antioxidant only in the presence of phenolic inhibitors. Following the initial findings with lard, Erdman, Watts and Ellias [9] found that ascorbic acid (0.1%) was ineffective when used alone as an antioxidant for salty fatty fish stored at 5°C. Liquid smoke alone (0.1%) was reasonably effective, but when combined with ascorbic acid the protective effect obtained was outstanding. Unfortunately this treatment also alters the flavor of treated products. It is to be hoped that in the future it will be possible to evolve a synergistic mixture of antioxidants that will protect fish very effectively against development of rancid flavors even during prolonged periods of frozen storage.

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THE NUTRITIVE VALUE OF HERRING MEALS

BY

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The Nutritive Value of Herring Meals

3. THE EFFECTS OF HEAT TREATMENT AND STORAGE TEMPERATURE AS RELATED TO OIL CONTENT

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Of the many investigations into the nutritive value of fish meals in poultry rations, most have been concerned with protein quality and with vitamin content. Little attention has been paid to the effect of oil content on the nutritive value of these meals.

Commercial fish meals normally contain from 5 to 10 percent oil. This oil, because of the temperatures reached in processing and the large surface area exposed in the final product, may be subject to considerable alteration through polymerization and oxidation. Bailey (1952), after reviewing the literature pertaining to the use of fish oils in animal feeds, states that the evidence indicates "that some fish oils contain a substance which is toxic to farm animals when the oil is fed in too large amounts." In experiments with rats, Crampton, Farmer and Berryhill (1951) showed that heat-polymerized oils (including herring oil) decreased growth and feed efficiency. It is known that the development of rancidity in unsaturated oils in a mixed feed may lead to the destruction of some of the vitamins, both fat and water soluble. For example, Lease *et al.* (1938) found that rancid fats inactivate vitamin A. Biotin has been reported by Pavcek and Shull (1942) to be similarly inactivated. Mattill and Golumbic (1942) found that the

* Contribution No. 87.

addition of rancid cod liver oil to the diet of rats resulted in dystrophy similar to that produced by vitamin E deficiency.

The present study was concerned with the effect of temperature and storage on the nutritive value for the chick of herring meals of various oil contents.

EXPERIMENT 1

Low-temperature herring meal was made by drying herring press cake at 37–43°C. in an air current. In order to test a low-fat meal, samples of this specially prepared meal were extracted with hexane at low temperature and the excess solvent was removed *in vacuo*. Samples of both the normal and the extracted meals were heated in 10-lb. lots in a rotating stainless steel drum at 149°C. for periods of 60, 120, and 180 minutes. The fat content of the non-extracted meals ranged from 7.30 to 7.55 percent, and that of the hexane-extracted meals from 0.15 to 0.28 percent. The experimental meals were incorporated in chick starting rations. In addition to the rations containing the normal and extracted herring meals, a third set of rations was formulated which contained the extracted meals and fresh herring oil. The amount of herring oil added corresponded to that contributed by the unextracted meals.

Ration 1 was composed as follows: ground yellow corn, 78.0; herring meal, 18.0; bonemeal, 0.5; limestone, 1.0; iodized salt, 0.5; dehydrated cereal grass, 1.0; choline chloride (25%), 0.4; manganese sulphate, 0.025 lb. per 100 lb. plus the following expressed as grams per 100 lb. nicotinic acid, 0.8; calcium pantothenate, 0.5; riboflavin, 0.2; fish oil (35,000 A), 6.0 gm.; and dry vitamin D_3, 18,000 units per 100 lb. Rations 2 to 12 were supplemented with the various herring meals as indicated in Table 1.

TABLE 1.—*Average weights of chicks fed unheated and heated, fat-extracted or unextracted herring meals as protein supplement in Experiment 1*

Ration No.	Treatment of meal	Weights in grams at 10 days (16 chicks per lot)		
		Lot A	*Lot B*	*Av.*
1	Unextracted, unheated	86	89	88
2	Unextracted, heated 60 min.	86	90	88
3	Unextracted, heated 120 min.	69	73	71
4	Unextracted, heated 180 min.	54	57	56
5	Extracted, unheated	89	90	90
6	Extracted, heated 60 min.	88	94	91
7	Extracted, heated 120 min.	90	90	90
8	Extracted, heated 180 min.	56	57	54
9	No. 5, fresh herring oil added	94	87	90
10	No. 6, fresh herring oil added	91	84	88
11	No. 7, fresh herring oil added	85	87	86
12	No. 8, fresh herring oil added	57	58	58

Adjustments were made so that the relative amounts of protein contributed by the corn meal and the herring meals did not vary throughout the experiment. Sucrose and water were added to compensate for the fat and water lost during the extraction and the heating. The rations were fed to day-old New Hampshire cockerel chicks kept in electrically heated battery brooders and given free access to feed and water.

The experimental data are shown in Table 1. When the chicks were ten days old, the experiment was terminated because the differences in growth of the chicks fed the various rations were obvious at this time. From the average weights of the chicks it appears that the oil content did not affect the nutritive value of the low-temperature meals or of those heated for 60 minutes. Heating at 149°C. for 120 minutes, however, impaired the nutritive value of the original meal but was without effect on the hexane-extracted meal. Heating for 180 minutes markedly reduced the nutritive value of both the original and the extracted meals. The addition of fresh herring oil to rations containing the extracted meals had no effect on the growth rate of the chicks fed these rations for the 10-day experimental period.

EXPERIMENT 2

Biely, March and Tarr (1952) found that the temperature employed in commerical processing of herring meal resulted in considerable destruction of the folic acid content. It was therefore considered possible that the heated meals retarded growth because of the destruction of folic acid rather than because of any direct effect of the oil itself. It will be noted that the rations fed contained only 1% of dehydrated green feed. This quantity would hardly meet the chick's need for folic acid if the particular sample of herring meal used did not contain a considerable amount.

An experiment was accordingly designed to determine whether the quality of the oil is important in itself or mainly by way of some indirect effect on the vitamins in the ration. Three samples of herring oil were tested for their effect. The first was a sample of fresh herring oil, the second a sample of the same oil that had been held at a heat of 110°C. for 30 hours and the third another sample of the same oil heated for 105 hours. To accelerate oxidation, air was bubbled continuously through the oil during the heating period.

The basal ration used was similar in composition to the diet in the previous experiment except that the dehydrated cereal grass was omitted. The herring meal used in the ration was a low-temperature meal which had been extracted with hexane. The oils were added to the ration at a level of 2 percent. The oil content of the rations containing the added oil was therefore comparable to the oil content of the ration containing the original herring meal. Each ration was fed with and without the following vitamins: folic acid, 0.035; thiamine HCl, 0.050; pyridoxine HCl, 0.160; menadione, 0.018; inositol, 5.0; alpha-tocopherol, 0.150; para-aminobenzoic acid, 4.5; biotin, 0.0045 and vitamin B_{12}, 0.0005 gm. per 100 lb. Except in rations 6 and 7, herring oil when added was mixed into the whole ration. In rations 6 and 7, the oil was mixed with the herring-meal content and allowed to stand overnight at a temperature of 21°C. The oil was absorbed by the herring meal and it was hoped that the mixture approximated the original herring meal.

TABLE 2.—*Average weights of chicks fed extracted and unextracted herring meals in Experiment 2*

Supplement to basal ration	Weights in grams of chicks at 4 wks. (20 chicks per lot)	
	Without vitamin supplement	With vitamin supplement
Control	207	256
Extracted herring meal	219	258
Fresh herring oil	168	261
Herring oil heated 30 hours	182	242
Herring oil heated 105 hours	185	272
Fresh herring oil*	185	—
Herring oil heated 30 hours*	162	—

* Herring oil mixed with herring meal and let stand at 21°C. overnight.

The rations were fed to day-old White Leghorn pullet chicks under conditions similar to those of the chicks in the previous experiment. The average weights of the chicks at 4 weeks of age are given in Table 2. The results show that when sufficient vitamins were added to the diet, growth was not retarded by the addition of any of the oils, whether fresh or heated. At the levels fed, therefore, the oils were not in themselves toxic. When, however, the basal ration was deficient in the vitamins, the addition of oil retarded growth. Heat treatment of the oils used in the present experiment did not seem to increase their growth-depressant action.

When the growth rates of the chicks fed either the original meal or the extracted meal were compared, no difference in nutritive value appeared as a result

of extraction. This was the case whether the rations were fortified with the additional vitamin supplement or not. The vitamin supplement stimulated growth to the same extent with both meals. When added to the rations without the supplementary vitamins noted above, all of the oils retarded growth of the chicks. The method by which the oil was added to the rations did not affect the nutritive value of the rations. Growth was retarded whether the oil was added directly to the mixed diet or blended previously with the herring meal.

EXPERIMENT 3

The third experiment in this series concerned three herring meals all prepared from the same sample of herring press cake. *Meal 1* was a low-temperature dried meal prepared according to the procedure already outlined. *Meal 2* was a typical light-coloured meal prepared commercially by direct flame-drying of press cake. *Meal 3* was a press cake dried at a much higher temperature than usual. The complete preparation of these meals* has been described by Tarr, Biely and March (1954). Samples of the three meals were extracted with hexane. Three growth tests with chicks were carried out to compare the nutritive values of the various meals.

The first test was carried out using a basal diet of composition similar to that in Experiment 2. The average weights of the chicks are given in Table 3. The basal diet supplemented with the low-temperature dried meal was superior in nutritive value to the commercially dried meals. It will be seen that in the commercially dried meals, overheating caused no greater deterioration than did the normal heating procedure.

Samples of the three meals described above were used in a further test to determine the effect of storage on the relative nutritive value of herring meals processed under different conditions. As part of this test, samples of the meals were extracted with hexane to ascertain if fat-free meals kept better than normal meals. The meals were stored at three temperatures, −25°, 21° and 37°C., for one year. The chick starting rations in which the various samples of meal were tested were similar to those used previously and were supplemented by the vitamins indicated for Experiment 2. In addition, the rations contained 0.25% of an antibiotic supplement.*

TABLE 3.—*Average weights of chicks* fed various extracted and unextracted herring meals in Experiment 3*

Description of herring meal supplement	Weights in grams of chicks† at 4 wks.	
	Unextracted	Extracted
Test 1		
Low temperature	257 (20)	258 (20)
Normal commercial	163 (15)	178 (12)
Overheated commercial	193 (10)	167 (11)
Test 2		
	Average weights in grams at 25 days	
	Stored at 21°C.	Stored at 37°C.
Unextracted low temperature	327	322
Unextracted normal commercial	335	302
Unextracted overheated commercial	307	—
Extracted low temperature	281	338
Extracted normal commercial	339	323
Extracted overheated commercial	316	—
Test 3		
Meals stored at −25°C.	Average weights in grams at 5 wks.	
Unextracted low temperature	470	
Unextracted normal commercial	476	
Unextracted overheated commercial	517	
Extracted low temperature	456	
Extracted normal commercial	508	
Extracted overheated commercial	518	

* Test 1: 20 White Leghorn pullet chicks per lot.
2: 25 White Leghorn cockerel chicks per lot.
3: 22 New Hampshire cockerel chicks per lot.
† Figures in parentheses represent the number of survivors at 4 weeks.

* Referred to as Meals 11, 2 and 6.

* Aurofac-A which contains at least 1.8 grams of aureomycin per lb.

TABLE 4.—*Stability of folic acid in different samples of herring meal stored for a year*

Description of herring meal	Mcg. folic acid per gram oil-free meal			
	Original	Storage temperature		
		0°C.	21°C.	37°C.
Extracted low temperature	9.6	5.4	5.4	3.8
Extracted normal commercial	0.72	0.44	0.40	0.32
Extracted overheated commercial	0.50	—*	0.40	—
Unextracted low temperature	—	—	6.7	4.0
Unextracted normal commercial	—	—	0.42	0.36
Unextracted overheated commercial	—	—	0.42	—

* No analysis.

The data given in Table 3 show that no marked differences occurred in growth rate. Even at a storage temperature of 37° C. there did not appear to be any loss in the quality of the meals. The presence or absence of oil in a meal did not, in general, result in any difference in nutritive value before or after storage. Meals dried at normal or excessively high temperatures kept as well as meals dried at a low temperature.

Since it had already been shown by Biely, March and Tarr (1952) that folic acid is particularly subject to destruction during the processing of herring meal, in the present test the folic acid content of the meals was determined microbiologically at intervals during the storage period. The folic acid content of the meals as shown in Table 4 dropped considerably during the year. The meals listed in this table as stored at 0°C. are samples which were kept in the laboratory refrigerator for use as reference standards with each assay. It will be seen that there was little difference between the folic acid content of these meals and that of the meals stored at 21°C. Extraction of oil from the meals before storage did not increase the stability of the folic acid in the meals, and, in fact, accelerated destruction of the vitamin.

DISCUSSION

The experimental data obtained in this study indicate that the oil content does not have an important effect on the nutritive value of herring meal used as a supplement in chick rations, provided the rations are adequately supplemented with vitamins. In Experiment 1 it was observed that heating more quickly reduced the nutritive value of a herring meal if the meal contained the normal amount of fat than if the meal was fat-free. The basal ration fed to the chicks in this instance was marginal in folic acid. When the basal ration in which the various herring meals and oils were tested was supplemented by folic acid and other vitamins, no adverse effect was noted from the addition of herring oil to the rations, regardless of the quality of the oil added. In Experiment 2 a sample of herring meal was tested in the original state and after hexane extraction. No difference in the nutritive value was noted, even when the basal ration was deficient in members of the vitamin B-complex. The addition of fresh or heat-treated herring oil to the ration containing the extracted herring meal, but not supplemented with the vitamin mixture, retarded growth of the chicks fed the ration. The adverse effect upon growth was completely overcome by the addition of the vitamins. Since there was no difference in growth whether the oil present in the herring meal was extracted or not, the oil naturally present in the meal evidently did not promote oxidation of vitamins in the ration. The sample of fresh herring oil and the two samples of heated oil still contained peroxides which destroyed some vitamin or vitamins present in suboptimal amounts in the ration and consequently lowered the growth rate of the chicks fed these rations. Possibly the oil in the herring meal was oxidized to the extent

that peroxides were destroyed. Lease *et al.* (1938) reported that heating of rancid fats lowered both their peroxide value and their ability to destroy vitamin A. In the present experiment a sufficient excess of the deficient vitamins completely overcame the growth-depressant action of the added herring oil.

The samples of herring meal which were tested for storage stability did not deteriorate in nutritive value as protein supplements during a period of one year. The basal ration in which the various meals were tested was well supplemented with vitamins. Extraction of the fat from the different samples of herring meal did not change their nutritive value as supplements to the basal ration employed, nor was the nutritive value of the extracted meals after storage different from that of those not extracted. It is particularly interesting to note that storage at a temperature of 37°C. had apparently no effect on the value of herring meals as protein supplements.

As was expected, the folic acid content of the meals dropped during storage. The stability of folic acid in the meals decreased with increasing storage temperature. In meals extracted with hexane before storage folic acid was less stable than in the original meals. The folic acid content of the normal commercial and the overheated commercial meals was so low that the difference observed between stability in the extracted and unextracted meals was insignificant. In the low-temperature dried meals held at 21°C., however, there was a difference of 1.3 micrograms of folic acid per gram in favour of the unextracted meal. It is possible that some natural antioxidants were removed from the meals with hexane.

Vitamin deficiencies encountered as the result of oxidation of vitamins present at marginal levels in mixed rations appear to be the basis for the alleged toxicity of rancid fish oils. The data obtained in the present study do not indicate that the quality of oil present in commercial fish meal is a factor in the nutritive value of fish meal even when fed at levels above those normally used in chick rations.

SUMMARY

1. In experiments with chicks it was found that the nutritive value of herring meal was not improved when the oil was removed by extraction with hexane. This was true of commercial flame-dried herring meal and of a low temperature dried meal.

2. When a low temperature dried herring meal was extracted with hexane the folic acid in the extracted meal was less stable than that in the original meal.

3. The nutritive value of herring meals stored for one year at −25°, 21° and 37°C. was apparently unaffected. The basal ration in which the herring meals were used was well fortified with both fat and water soluble vitamins.

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